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Proceedings of the 38th Southern Pasture and Forage Crop Improvement Conference

June 7-10, 1982
Blacksburg, Virginia

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CONTENTS

PRODUCTION AND YIELD OF SILAGE CROPS IN THE SOUTH

J. Kenneth Evans

University of Kentucky

INTRODUCTION

Stored-feed requirements in the Southeastern United States vary from practically none on range cattle to almost 100% on the large dairy operations and finishing lots. Since the two biggest nutrient requirements are for energy and protein, yields of these two components are of obvious primary interest to farmers. There may also be a need for crops which will fill some emergency need or will fit into some time niche in either the weather pattern or other cropping patterns of an area. It is the purpose of this paper to summarize some of the research yields of dry matter and protein, and in some instances, animal production obtained from silage crops grown in the South. No attempt will be made to summarize all of the cultural-practice effects--e.g., nitrogen, plant population, etc.; rather, the data will be examined more in terms of the yield potential and range in yields which have been obtained. Data are included from Florida, Georgia, Tennessee, Louisiana, Kentucky, and Virginia.

FORAGE SORGHUM, SWEET SORGHUM, SORGHUM X SUDANGRASS HYBRIDS

Highest yields of dry matter (23.7 tons/acre) in the data examined were obtained with a forage sorghum variety grown at Ona, Florida in 1980. Four forage sorghum hybrids averaged 14.6 tons of dry matter (DM) per acre over a 5-year period (Table 1). Sweet sorghum hybrids (Table 2) and sorghum X sudangrass hybrids (Table 3) also produced high DM yields when rows were 18 or 30 inches apart and cuttings were made at near dough stage of maturity. Sorghum X sudangrass yields were very low and stands were quickly lost when row spacings were six inches and cuttings were made when plants were in a vegetative stage of growth.

Table 1.--Dry matter yields of irrigated forage sorghum hybrids in south Florida

	Seasonal DM Tons/A
Ave. 13 Vars. 1980[1]	13.6
Highest Var. 1980[1,2]	23.7
Lowest Var. 1980[1]	8.4
Four Vars. 5-Yr. Ave.	14.6

[1]30" rows, 3-har., 465 lbs/A of N.
[2]Never had seed at harvest.

Source: Kalmbacher et al., Ona, Florida. Research report RC-1981-2.

Table 2.--Dry matter yields of irrigated sweet sorghum hybrids in south Florida

Variety	Seasonal DM Tons/A
Brandes, 1976	14.0
Rio, 1976-77	12.0
Ramada, 1977	9.4

Rows, 18" 1976, 30" 1977, two harvests, 300 lb N/A

Source: Kalmbacher et al., Ona, Florida. Mimeograph.

Table 3.--Dry matter yields of irrigated sorghum x sudangrass hybrids in south Florida

	Seasonal Dry Matter, Tons/A	
	30-inch rows[1]	6-inch rows[2]
Ave. of 12 varieties in test	11.3	1.9
Highest variety	14.9	2.4
Lowest variety	6.7	1.8

[1]3 harvests, 367 lbs N/A, all 1st harvests at dough stage. A few varieties did not reach dough again.

[2]2 harvests, 202 lbs N/A, cut each time at 30-36" high. Stand life shortened by the early harvest as would be practiced in grazing management.

Source: Kalmbacher et al., Ona, Florida. Research report RC-1981-1.

Table 4.--Dry matter (DM) yield and ratios of corn grain to stover in several southeastern states

State	DM Yield, T/A		Grain:Stover, %	
	Ave.	Range	Ave.	Range
Florida-Irrigated	7.9	4.2-10.9	49:51	32:68-62:38
Georgia-Irrigated	3.9	2.9-4.8	[1]46:54	41:59-51:49
-Non-Irrigated	4.0	3.2-4.9	[1]44:56	40:60-49:51
Kentucky-Non-Irrigated	7.1	4.2-10.0	47:53	40:60-60:40
Louisiana-Irrigated	6.0	4.7-7.3	-----	-----------
-Non-Irrigated	3.5	2.7-4.8	24:76	17:83-39:61
-Non-Irrigated	5.1	4.7-5.4	-----	-----------
Virginia-Non-Irrigated	10.1	9.7-10.5	-----	-----------

[1]% ears:stover.

Table 5.--Dry matter yields, quality factors and/or animal performance on corn, grain sorghum, and soybeans alone and in combination in four southeastern states

State	DM Yield, T/A Ave.	DM Yield, T/A Range	C.P., %	C.P./ Acre, lbs	Crude Fiber, %	Silage DM Intake lbs/Day/Cow	Milk Prod., lbs/Day
Georgia-Corn	3.9	2.9-4.9	7.7	601	27.7	----	----
-Corn + Soybeans	4.1	3.5-4.8	8.8	722	29.4	----	----
-G.S.	4.8	4.4-5.2	7.8	749	28.6	----	----
-G.S. + S.B.	4.4	3.7-4.9	9.0	792	30.2	----	----
-Soybeans	1.4	0.9-2.0	13.1	367	35.6	----	----
Kentucky-Corn	9.5[1]	-------	9.5	1805[1]	22.1[5]	25.4	59.7
-G.S. + S.B.	4.6[1]	-------	10.1	927[1]	36.8[5]	22.4	52.1
Tennessee-Corn	4.9	-------	8.7	840	24.5	----	36.8[6]
-G.S. + S.B.	3.5	-------	13.1	900	30.5	----	33.8[6]
Virginia-Corn	9.7	-------	7.5	1450	----	----	----
-G.S. + S.B.[2]	5.8	-------	10.2	1181	----	----	----
-G.S. + S.B.[3]	4.2	-------	17.3	1452	----	----	----
-G.S. + S.B.[4]	5.5	-------	14.0	1545	----	----	----

NOTES

G.S. = Grain Sorghum; S.B. = Soybeans; DM = Dry Matter; C.P. = Crude Protein

[1]Yields were estimated by counting corn plant population and sampling for individual plant weights in corn. G.S. + S.B. yields were estimated by weighing several wagon loads, sampling for moisture and calculating DM yields from a known land area.

[2]G.S. + S.B. combination having the highest DM yield.

[3]G.S. + S.B. combination having the highest % protein.

[4]G.S. + S.B. combination having the highest protein production per acre.

[5]Acid detergent fiber (ADF).

[6]Jersey cows.

CORN, SOYBEANS, AND INTERPLANTED GRAIN SORGHUM + SOYBEANS

Corn silage has long been recommended as the highest yielding and quality silage crop for the eastern United States; however, yields in the deep south have been historically low. Data in Tables 4 and 5 show that quite high yields can be obtained in Peninsular Florida (10.9 T/A) and Louisiana (7.3 T/A) if water and nitrogen are applied as needed throughout the growing season. Other data, not included in this paper, show high yields at Quincy, Florida also. Timely planting is critical if maturity is to be achieved and harvesting accomplished before summer rains begin. On the high-organic-matter soils of South Florida, frosts which would only produce marginal leaf burning in the upper south and northern states penetrate to and kill the growing point of corn. This is apparently due to a specific heat of organic soils which is lower than that of mineral soils. Note the range in yields for several irrigated experiments in Florida is almost the same as the range in yields for several unirrigated experiments in Kentucky (Table 4), reinforcing the need for irrigation of winter-grown corn in Florida.

During the last few years, there has been a big promotion of the practice of interplanting grain sorghum (GS) and soybeans (SB) for silage over the southeast. Advantages are supposed to include (1) higher yields of protein, (2) more than one crop per year (i.e., replanting soybeans to grow with a ratoon crop from the grain sorghum), and (3) "balancing the ration" in the storage structure. Data on this practice are now available from Georgia, Kentucky, Tennessee, and Virginia (Table 5). Research has also been done in Mississippi, but results were unavailable for use in this paper. Several interesting factors are obvious from these data. Dairy feeding trials in both Kentucky and Tennessee showed that milk production was lower when cows were fed properly supplemented GS + SB silage rations than on properly supplemented corn silage rations. Corn silage intake was higher, probably due to the higher fiber in GS + SB rations.

Although no feeding trials comparing GS + SB with corn silage were conducted in Virginia, their yield data are quite interesting. They report combinations of GS and SB which more closely approximate the recommended 50:50 ratio than any data located. When one calculates protein production per acre from the three treatments which produced highest DM yields, highest percentage protein and the best combination of yield and protein content, only the latter treatment produced slightly more total protein per acre than corn. Corn, however, produced about 50% more total dry matter. The wisdom of sacrificing half of the energy to increase protein by 95 lbs/acre seems questionable (Table 5).

Obviously there are special situations where GS + SB may be the best choice. It would appear that one would be unwise to choose this option if length of season, available soils and other conditions would permit growth of corn. It is also questionable if the two crops should be grown in the same field or perhaps in different fields. Management is simplified in pure stands. For example, no herbicides are available for use on the GS + SB combination. Serious weed problems have been experienced on some Kentucky research plots and farms. Obtaining a 50:50 stand of GS + SB and selecting compatible varieties which are both ready for harvest at the same time can be quite difficult. Nitrogen fertilization rates which are proper for grain sorghum are inappropriate or unnecessary for properly nodulated soybeans and would probably decrease nodulation and resulting N_2 fixation by soybeans. It has yet to be shown that crops growing in association with or following well-nodulated soybeans obtain very much nitrogen from the soybeans.

MISCELLANEOUS CROPS - SORGHUMS, MILLET, AND COWPEAS

Data on these crops are shown in Tables 6 and 7. Although DM yields of millet, NK 300 sorghum and cowpeas were relatively low in southeast Louisiana, they were all excellent quality forage. Digestible dry matter was 65, 65, and 64% and crude protein was 17.7, 16.3, and 22.2% respectively (Table 7). Data on several millets grown at Ona, Florida also show yields much lower than other plant species grown at that location (Table 6). Low DM yields, rapid growth, and high quality of these species suggest perhaps they would be better suited for creep grazing than for silage harvest.

ALFALFA

Alfalfa has been long recognized as the highest yielding protein forage legume available in areas of the U.S. where it is adapted. The number of problems associated with growing alfalfa in the lower south far exceeds solutions; nevertheless, interest continues high. In the upper south, alfalfa acreage decreased rapidly in 1965 after the heptachlor label was withdrawn as a control for alfalfa weevil. Acreage is now increasing at an increasing rate and there are literally dozens of high-yielding varieties available for use. Alfalfa DM yields at Lexington, Kentucky are shown in Table 8. Both the 5-year and 1981 averages showed about a 0.7 t/acre yield advantage by selection of one of the top 5 varieties in the test. Although protein yields were not determined in that experiment, yields of over 3,200 lb of crude protein per acre have been produced by alfalfa in Kentucky.

Harvesting and curing hay without rain damage is difficult in the humid east. Multiple harvests of a crop such as alfalfa increase the probability of weather damage. Ensiling could

Table 6.--Dry matter yields of sudangrass and pearlmillet hybrids grown at Ona, Florida, 1980

Brand	Hybrid	Harvest 1 5/2/80	Harvest 2 6/3/80	Total
		- - - - - - DM, Tons/Acre - - - -		
Northrup King	Trudan 8	0.89	0.93	1.82 a
Georgia AES	Gahi-3	0.88	0.59	1.47 a
Georgia AES	Tifleaf	0.82	0.33	1.15 a
Northrup King	Millex 24	0.79	0.00	0.79 b
Ring Around	MH 99	0.78	0.00	0.78 b
Gold Kist	Millgreen 79	0.71	0.00	0.71
Average		0.81	0.62	1.12

NOTES

Date seeded: March 6, 1980
Seeding rate: Pearlmillet, 6 lb/A; sudangrass, 10 lb/A. Plots drilled with rows 6" apart.
N Fertilization: 172 lbs N/A prior to harvest 1; 44 lbs N/A after harvest 1.
Irrigation: Overhead with 1.75 inches.

Source: Kalmbacher et al., Ona, Florida. Research report RC-1981-1.

Table 7.--Dry matter, digestible dry matter, and protein yields of millet, sorghum and cowpeas in southeast Louisiana, 1978-80

Cultivar	Dry matter, lbs/A	Digestible DM, lbs/A	Crude Protein, lbs/A
Millett, Millex 23	6033	3929	1069
Sorghum, NK 300	4480	2893	729
Cowpea, Big Boy	2957	1886	655

Source: Annual Progress Reports, Southeast La. Exp. Sta., 1978-80.

Table 8.--Dry matter yields of alfalfa at Lexington, Kentucky

	Average Dry Matter Yield, Tons/A
Top 5 varieties tested 1977-81	5.36
Bottom 5 varieties tested 1977-81	4.63
Top 5 varieties tested 1981	7.62
Bottom 5 varieties tested 1981	6.78

NOTES

Sown in May 1977, therefore stand was 5 years old in 1981.

Source: Sigafus and Taylor, University of Kentucky, Progress Report 260.

essentially solve this problem, but most farmers do not have and probably cannot economically justify conventional silage systems. For the past two years Kentucky researchers have been looking at possible systems for round baling both wet hay and silage.

In 1981 28½-percent-moisture fourth-cutting alfalfa was baled at Lexington, Kentucky with a New Holland round baler. Three bales weighing about 1,500 pounds each were placed end-to-end on pallets and covered with black plastic. A wind-driven attic turbine was mounted at the center of the bale row and sealed in such a manner that moist, heated air was exhausted from around the bales and fresh air drawn into the bale stack from around the pallets. After about one week, moisture levels in bales had dropped and remained at 15½ percent. An uncovered bale reached 15½ percent in about one month, after which it was wetted by rain and remained wet until sampling was stopped in December. Third-cutting alfalfa hay was baled at less than 20 percent moisture and loosely covered with black plastic to keep out rainfall.

Alfalfa for ensilage was baled with a New Holland round baler during the 1980 and 1981 growing seasons. In 1980, 65-percent-moisture bales were individually wrapped and sealed in black plastic and stored in a shady area. In 1981, 68-percent-moisture bales were placed end-to-end along the edge of a 24-foot by 100-foot plastic sheet. The plastic was then pulled over bale rows; edges were rolled and sealed at the soil surface by placing ground limestone around the ends and one side. Rows were stored in direct sunlight. In both years, bales were sealed within less than one hour after baling. Silage

Table 9.--Alfalfa hay and silage, voluntary intake, average daily gain, and percent not eaten by dairy heifers

	DM Intake % BW	ADG, Lbs/Day	Percent Not[4] Eaten
Hay, 4th Cutting[1]	2.24	1.48	18.35
Silage, 4th Cutting[2]	2.10	----	0.66
Hay, 3rd Cutting[3]	2.03	1.41	33.00
Silage, 3rd Cutting[2]	1.43	----	29.69

NOTE

DM = Dry Matter; BW = Body Weight; ADG = Average Daily Gain

[1]Hay round baled at 28% moisture, bales stored on pallets under black plastic and dried with Wind Assist Solar Hay Drier (WASHD).
[2]Silage baled at about 65% moisture. Bales totally enclosed under black plastic.
[3]Hay round baled at about 20% moisture and stored on the ground under black plastic.
[4]Calves were not forced to clean up feed on obviously poor quality hay or silage.

Source: University of Kentucky Progress Report 264, 1981.

quality looked and smelled excellent in 1980 and not as good in 1981.

In 1980, all baled silage was fed to mature, dry ewes as a maintenance ration. The silage was eaten well and ewes gained two pounds per head over the feeding period. In 1981 both the round baled silage and hay were fed as the only source of feed to young dairy heifers. Results of those experiments are shown in Table 9. Third- and fourth-cutting hay and fourth-cutting silage were all eaten in quantities greater than two percent of body weight, which indicates quality was rather good. Average daily gains of 1.41 and 1.48 pounds on the third- and fourth-cutting hay, respectively, also indicate high quality. Hay-feeding losses were due to moldy hay which calves were not forced to clean up. The extremely low (0.66 percent) feeding loss from fourth-cutting silage is consistent with the observed excellent quality. Third-cutting silage which had been in storage longer than the fourth cutting was not eaten well. It is possible that lowered quality with longer storage may be due to: (1) heating of silage sealed in black plastic and stored in direct sunlight, (2) permeability of plastic which permitted oxygen to enter and/or organic acids to volatilize and escape, and/or (3) lower bale density and more trapped oxygen caused by baling at high ground speed and, as a result, poorer lactic acid production.

Research in 1982 will be continued on both hay and silage. It will include ensiling of fescue, red clover, and alfalfa sealed in high-quality black and white plastic bags. Bales will be stored outside or in shade and temperatures will be measured throughout bales. Feeding trials as well as chemical analyses will be used as quality indicators.

SUMMARY

Exceptionally high yields of dry matter are possible from crops which can be grown in the Southeastern United States. As one would expect, yields at a particular location may be dramatically affected by species and/or variety, row width, available soil moisture, nitrogen rates and time of application, and plant population. It would appear that, where adapted, corn is a better alternative for both energy and total protein production than is intercropped grain sorghum and soybeans. Alfalfa is the highest yield alternative for both percentage and total protein. Ensiling of alfalfa has been successfully accomplished by mowing, wilting to 57-68% moisture, raking, round baling, and sealing in plastic. Research on this method of ensiling as well as solar drying of high-moisture hay stored under black plastic is being conducted at the University of Kentucky.

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MACHINES, ENERGY, AND TIME IN SILAGE MAKING

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INTRODUCTION

Silage making requires coordination and productivity balancing of several machines and anywhere from 3 to 6 workers. Field chopping rate sets the materials handling requirements for transport and storage machines. When properly organized chopping progresses without undue delays caused by transport or handling. Problems arise when field conditions impair chopping rate; transport distances change; machines break down; and labor crews are only partially manned. Silage making requires planning and coordination and such management must be happening, otherwise, the annual U.S. silage production of 150 million tons would be decreasing rather than increasing.

In spite of the rather high energy use for mechanical chopping of silage and transporting large amounts of water, silage making saves labor to offset higher fuel use when compared to hay making. Still silage making is a complex process requiring simultaneous use of separate machines, several coordinated workers, and considerable fuel. One of the latest technical developments in silage making was oxygen-free storage. This technology is now a generation old. The next "break-through" will probably center on machine designs which improve energy efficiency of silage chopping, transport and handling, and manipulation of silage making with additives of various types to increase the feed energy density and digestibility per unit volume of material handled, stored, and fed.

ENERGY AND LABOR IN SILAGE MAKING

Silage making involves separate machines for chopping, transport, materials handling, and unloading. All except the unloading machines are powered by diesel engines. For chopping, power increases directly with harvesting rate (tons/hr) and with decreasing lengths of cut. Moisture content has some infuence on

the energy requirement for chopping but within the normal silage range the variations are small. Some crops chop more easily than others. Corn for example, at a given cut length requires about 70% of the energy needed to chop a grass crop. When cut lengths increased from 1/4 in. to 3/8 in., the energy dropped 15% in corn and 25% in alfalfa. At the 3/8 in. cut length the actual average forage particle length was 3/4 in. for alfalfa and 1/2 in. for corn (PAMI, 1981). At a particular cut length setting, a chopper produces a range of particle lengths. This variation has little effect on ensiling properties or animal acceptance and utilization. However, too many long particles may create problems with silage unloading equipment. Short cut lengths and improved energy efficiency for silage chopping are conflicting factions, but for the present adequate fuel supplies favor short cut lengths. Research on cut length 4 to 10 time current practice should be initiated and the results in place for future use if and when a severe diesel fuel shortage occurs and in the interest of fuel conservation.

Slightly more than 1/2 of all fuel used for silage making is required for chopping. Labor for chopping was about 1/4 of the total labor required in silage making. Transport and handling silage required 1/2 of the total fuel and 3/4 of the labor.

Table 1.--Labor (man-hrs) per day for silage making

Type Silage	Tons/Day	Chopping	Transport	Store	Min/Ton
Corn silage (tower)	150-200	4	16	3	9
Corn silage (bunk)	150-200	4	9	4	7
Wilted grass (tower)	100-140	5	11	3	13*
Wilted grass (bunk)	100-140	5	6	3	11*

*Includes labor for mowing and windrowing.

When transporting corn silage to tower silos in self-unloading wagons, one load at a time, the labor requirements for transport exceeded that of chopping by a factor of 4 (Table 1).

Dump trucks were used to transport silage to bunk type silos compared to self-unloading wagons for tower storage. Transport distance was 1 mile. Trucks reduced the transport labor by 50% over self-unloading wagons. Trucks also reduced fuel used for transport by similar amounts (Table 2). These comparisons indicate the potential labor and fuel savings by using alternative silage transport methods.

Table 2. Fuel need (gal. of diesel fuel) per day for silage making

Type Silage	Tons/Day	Chopping	Trans.	Store	Gal/Ton
Corn silage (tower)	150-200	35	27	13	.4
Corn silage (bunk)	150-200	35	11	13	.3
Wilted grass (tower)	100-140	47	18	10	.7*
Wilted grass (bunk)	100-140	47	8	9	.6*

*Includes fuel for mowing and windrowing.

INFLUENCE OF DRY MATTER LOSSES

Any dry matter loss during harvesting, storage, or feeding leaves behind their portion of fuel and labor inputs to be distributed over a shrunken DM base. This increases inputs per unit of DM remaining. For example, a 20% DM loss in storage increases the fuel and labor investment per ton of remaining DM by 25%. Conserving DM throughout the system in turn conserves fuel and labor.

Typical DM losses for various forage harvesting methods are are shown in Table 3.

Table 3. Average DM losses (in percent) for various forage harvesting methods

Method	Mow & Cure	Harv.	Stor	Feed	Total loss (% of crop)
Corn silage	-	5	6	4	14
Wilted grass	6	5	7	11	24
Baled hay[1]	10	3	4	5	20
Round bales*	10	10	12	14	39

*Stored outdoors 6 mo. and fence line fed
[1]No rain damage

When DM loses such as those shown in Table 3 occur, the fuel and labor inputs during harvesting and handling change accordingly.

Table 4. Labor and fuel comparisons for various forage systems with typical DM losses (values shown on basis of DM available and acceptable for feed)

System	Labor per ton DM	Fuel per ton DM
1. Silages, tower silos, SUW, un-ldr. feed-bunk	1.1 hr	2.1 gal
2. Silages, bunk silos, trucks, feed wagon & bunks	.8 hr	1.7 gal
3. Hay bales, manual loaded self-feed rack, indoor storage	2.0 hr	.7 gal
4. Round bales, transporter, outdoor storage (6 mo), fence line feeder	1.6 hr	1.4 gal

From Table 4 data, the general comparison between silage and hay indicates that silage systems require twice as much fuel as hay systems per ton of DM fed and 1/2 of the labor. A major portion of operating costs can be obtained from Table 4 (on ton DM basis) by utilizing wage rate per hour and fuel costs per gallon. Machinery repair, twine, etc. costs should be added for a more precise estimate. For example, if labor costs $5 per hour and diesel fuel $1.20 per gallon, then operating costs (without repairs) for systems in Table 4 would be as shown in Table 5.

Table 5. Labor and fuel costs for various forage systems

System	Labor cost per ton DM	Fuel cost per ton DM	Total
1. Silages, tower silos, SUW, un-ldr, feed bunk	$5.50	$2.52	$8.02
2. Silages, bunk silos, trucks, feed wagon & bunk	$4.00	$2.04	$6.04
3. Hay bales, manual loaded, self-feed rack, indoor storage	$10.00	$ .84	$10.84
4. Round bales, transporter, outdoor storage (6 mo), fence line feeder	$8.00	$1.68	$9.68

SUMMARY

At the present level of technology neither silage nor hay type forage systems appear to have the benefit of both reduced labor and low fuel inputs. Silage making has a low labor but high fuel input. Hay systems tend to be the opposite.

In silage systems a disproportionate share of both labor and fuel goes into transport if traditional tractor-wagon combinations are utilized. New designs for transport machines can help this problem.

Increasing the length of cut on forage harvesters will almost return a proportional reduction in energy requirement and fuel saved. At the present time short cut lengths are advocated primarily to facilitate materials handling and compaction. Length of cut needs further research which includes energy and handling analysis as well as feed quality and utilization. Along with silage additives for improved feed energy density, these two areas represent significant research challenges in silage making.

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PRINCIPLES OF SILAGE FERMENTATION AND THEIR APPLICATION IN THE SELECTION OF ADDITIVES

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INTRODUCTION

The goal of successful silage fermentation is maximum preservation of the energy and protein available in the ensiled crop for use by animals. The crop characteristics and handling during ensiling must be optimized in order to maximize preservation. Ensiling excessively wet feeds will increase the degradation of both energy and protein. Ensiling excessively dry feeds will increase aerobic losses initially, during compaction, and later during silage removal, thus heating and binding protein with carbohydrate, which decreases digestibility. A stable, minimal, and efficient anaerobic fermentation is needed. The fermentation reaches a reasonably stable conclusion primarily on the basis of final pH and dry matter. Water-soluble carbohydrates in the ensiled feed are the primary substrate for acid production. The amount of acid required to attain a stable pH is dependent on the initial buffering capacity of the ensiled feed. The efficiency of fermentation may range from an efficient homofermentative type producing only lactic acid, to an intermediately efficient heterofermentative type producing both lactic and weaker acids, to an inefficient alcohol fermentation that has no effect on pH. Successful additives for excessively wet silages must supply either end products of fermentation, which then limit natural fermentation; additional substrate; or adjuncts for a more efficient fermentation. Successful additives for excessively dry silages must control aerobic losses.

PRINCIPLES OF ENSILING

Requirements for a Stable Fermentation

The primary limiting conditions for acid-stabilized fermentation are pH and water activity. Dry matter (DM) percentage is a simple and practical expression of water activity. Wieringa (1969) described the relationship between pH and DM that separated stable silages from unstable silages (figure 1). Stable silages occur if

$$\% \text{ DM} \geq 25 \text{ (pH)} - 80 \quad (1)$$

and unstable silages occur if

$$\% \text{ DM} < 25 \text{ (pH)} - 80. \quad (2)$$

For example, silages at 20% DM are stable when pH $\leq$ 4.0 but silages at 35% DM are stable when pH $\leq$ 4.7. This same general relationship between DM and pH is supported in the data of Weissbach et al. (1974). This relationship has the important practical meaning that pH alone cannot be used as the criterion of a stable and successful silage.

Substrate Characteristics Predicting a Stable Fermentation

The major substrate for anaerobic fermentation is sugar (S) or water-soluble carbohydrate for production of organic acids. The effectiveness of the acids in reducing the pH is primarily dependent on the buffering capacity (BC) of the initial ensiled crop. Weissbach et al. (1974) combined S and BC in a model as the ratio S/BC and described the relationship between S/BC and DM that separated stable from unstable silages (figure 2). Stable silages occur if

$$\% \text{ DM} \geq 45 - 8 \text{ (S/BC)} \quad (3)$$

where S = sugar as percentage DM
BC = buffering capacity as grams of lactic acid/100

grams of DM required to reach pH 4.0.

Unstable silages occur if

$$\% \text{ DM} < 45 - 8 \text{ (S/BC)}. \quad (4)$$

Wilkinson et al. (1981) challenged this model after obtaining a greater reduction in variance from considering the separate effects of DM, S, and BC. However, they did not present a specific equation in their summary and did not introduce any new parameters.

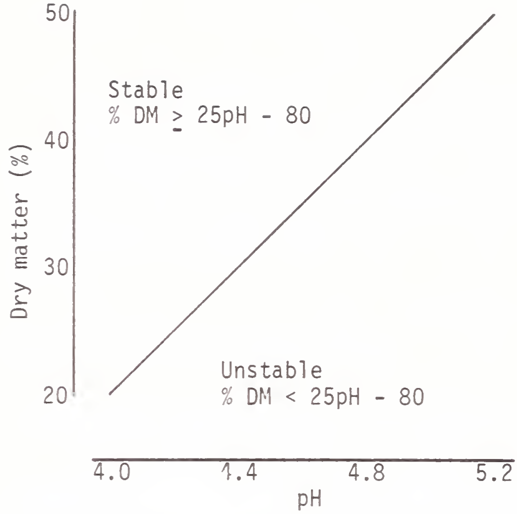

Figure 1.--Relationship of dry matter and pH that separates stable and unstable silages (Wieringa, 1969).

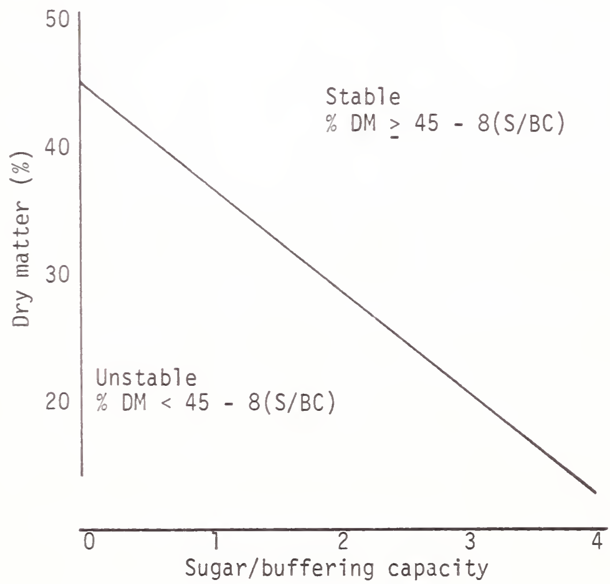

Figure 2.--Relationship of dry matter and sugar/buffering capacity ratio that separates stable and unstable silages (Weissbach et al., 1974).

Crop Characteristic Affecting a Stable Fermentation

Considerable variation exists in DM, S, and BC values of major crops being ensiled (table 1). Generally, S is lowest in legumes, intermediate in grasses, and highest in corn. BC is highest in legumes, intermediate in grasses, and lowest in corn. The DM at harvest varies; grasses and legumes are near 20% and whole corn plant is near 35% at physiological maturity. Based on S/BC, corn can be successfully ensiled at a considerable range of DM°s around 35%, but grasses require some wilting and legumes require more wilting to be successfully ensiled without additives.

Alcohol Fermentation

The model of Weissbach et al. (1974) does not deal directly with the relative probabilities of efficient lactic, intermediate heterofermentative, or inefficient alcohol fermentations. Wetter corn silages produce large amounts of alcohol. Corn silage at various percentages of DM produced the following ethanol concentrations: 40 to 45%, .37%; 35 to 40%, .47%; 30 to 35%, 1.28%; 25 to 30%, 2.76% and 20 to 25%, 4.86% of DM (Andrieu, 1976). Ethanol concentrations as high as 6.7% of DM have been observed in corn silage (Austin et al. 1978). Because the energy concentration per unit weight of ethanol is nearly double that of sugars, these ethanol concentrations multiplied by two would approximately equal the amount of sugar diverted from potential lactic acid production. The ethanol concentration approximately equals the loss of DM that must occur in its production. Presumably, a yeast fermentation produces this ethanol; such fermentations probably contributed to the extensive DM losses observed by Ramsey et al. (1961) for ensiled sweet sorghum. Apparently, grasses and legumes contain a calcium-precipitable inhibitor of sediment yeast fermentations (Olsen and Pedersen, 1974) that prevents alcohol fermentation in direct-cut hay crops. The sediment yeast *Torulopsis* sp. can produce alcohol from sugar anaerobically (Beck, 1978). Thus, yeasts increase and produce more ethanol as silages become wetter, except where inhibitors are present as in grasses and legumes (M. K. Woolford, The Grassland Research Institute, personal communication).

Relation of Dry Matter and Protein Degradation

Protein degradation is decreased by ensiling drier crops even though the silages are free of clostridia and their consequent protein degradation. Silages that contain more undegraded protein will be better feeds for high levels of production from ruminants. The regression equation derived

from the data of Hawkins et al. (1970) for alfalfa (figure 3) is

$$Y = 23.6 + .63\ X \tag{5}$$

where Y = insoluble N as percentage of total N
X = DM percentage in silage.

Wilkinson (1976) analyzed data from 20 corn silages and found that (figure 4)

$$Y = 70.8 - .77\ X \tag{6}$$

where Y = soluble N as percentage of total N
X = DM percentage in silage.

The plots of Andrieu and Demarquilly (1974) also support a positive relationship between silage DM and insoluble N as percentage of total N. This positive relationship also holds for ensiled high-moisture corn grain (figure 5). Sprague and Breniman (1969) found that

$$Y = 187 - 2.03\ X \tag{7}$$

where Y = soluble N as percentage total N
X = DM percentage in ensiled corn grain.

Thornton (1976) found that

$$Y = 334 - 4.02\ X \tag{8}$$

where X and Y are as defined for equation 7.

At 68% DM, equations 7 and 8 predict 49% and 61% soluble N, respectively; at 80% DM, they predict 25% and 12% soluble N. These two prediction equations for high-moisture corn are not particularly close. The positive relationship between DM and conservation of insoluble nitrogen or preserved protein generally seems to apply to all ensiled feeds.

Aids to Ensiling Based on Principles

The model of Weissbach et al. (1974) implies that making of good corn silage will be easy, making good grass silage will be intermediately difficult, and making good legume silage will be difficult. This model implies that wilting is one way of making more good silages from grasses and legumes. Other ways implied from the model are direct acidification to lower the pH, addition of more substrate for acid production in the fermentation, and additives to make the fermentation more efficient.

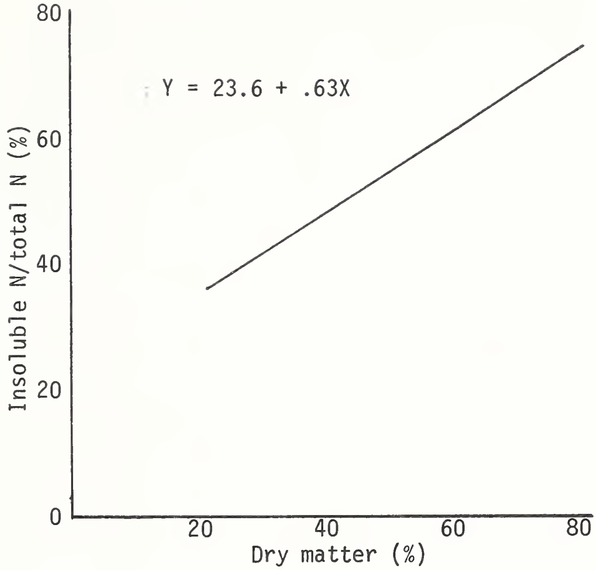

Figure 3.--Relationship of insoluble nitrogen as a percentage of total nitrogen to dry matter of ensiled alfalfa (Hawkins et al., 1970).

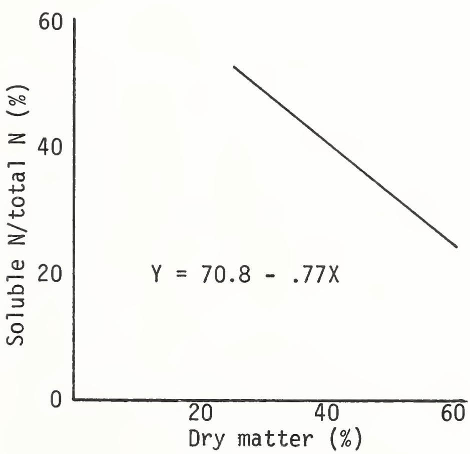

Figure 4.--Relationship of soluble nitrogen as a percentage of total nitrogen to dry matter of ensiled whole plant corn (Wilkinson, 1976).

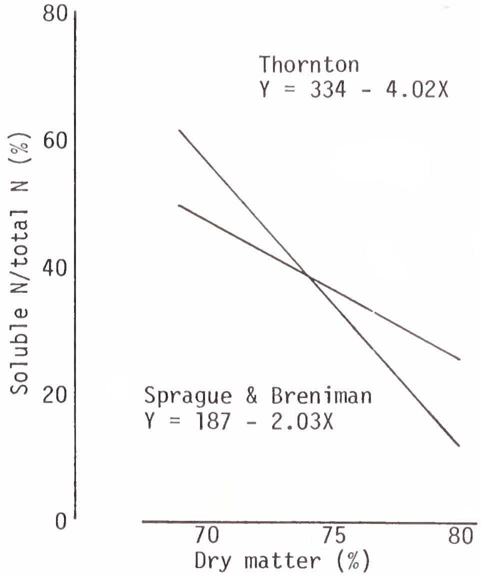

Figure 5.--Relationship of soluble nitrogen as a percentage of total nitrogen to dry matter of ensiled corn grain (Sprague and Breniman, 1969; Thornton, 1976).

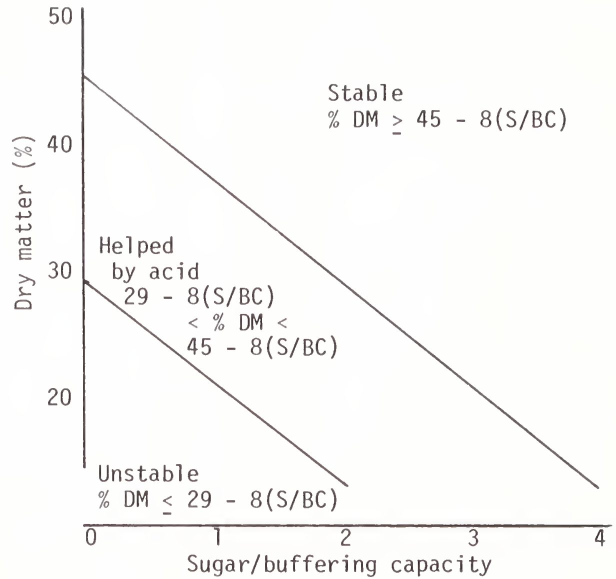

Figure 6.--Relationship of dry matter and sugar/buffering capacity ratio for silages that can be helped by direct acidification with formic acid (Weissbach et al., 1977).

Table 1.--Average compositions of various herbages for ensiling[a]

Criteria	Alfalfa	Italian ryegrass	Whole-plant corn
Sugar (% DM)	6.0	14.0	23.0
Buffering capacity (g lactic acid/100 g DM)	7.4	5.6	3.5
Sugar/buffering capacity	0.8	2.5	6.6
Dry matter (%)			
At harvest	20	20	35
For stable silage	39	25	25

[a]Weissbach et al. (1974).

Table 2.--Average daily tonnage of dry matter required to obtain 25 lb/ft density in silos in 3 days[a]

Diameter of silo	Herbage dry matter (%)		
	30	40	50
(ft)	-------(U.S. tons/day)------		
16	2	4	9
20	3	6	14
24	4	9	21

[a]Values read from figure 13b of Wood (1971).

Table 3.--Effect of silo size on percentage of dry matter needed to prevent seepage and heat damage in hay crops

Silo size		Dry matter			Time in optimum range[b]
		Limits[a]			
Diameter	Height	Lower	Upper	Range	
		----------(%)-----------			
16	40	30	60	30	7.5
32	80	34	46	12	3

[a]Lower limits are based on data from Daynard and Arnold (1974); upper limits are based on data from Wood (1971), assuming that 30 tons of DM can be ensiled daily.

[b]Assuming a drying rate of 4 percentage units per hour.

PROBLEMS OF WILTING FOR SILAGES AND ADDITIVES

Extension advisors have recommended and farmers have used wilting of grasses and legumes even without the aid of this formal model and its equations. Well-made wilted silages are an excellent way of preserving hay crops. Unfortunately, wilting is dependent on the weather and presents a difficult management challenge. Some new problems are introduced.

Heat Damage

Excessive wilting brings on the problem of excessive heating in storage. This heating increases losses and decreases the digestibility of protein and energy. Goering et al. (1974) estimated that 20% of potentially digestible protein in surveyed hay-crop silages was indigestible as a result of heating; minimal heat damage occurred in corn silages. Thomas (1976) described the heat damage, which was measured as acid detergent-insoluble nitrogen (ADIN), as a function of heating degree days in the silo above 35C as

$$Y = .175 + .00054\ X \tag{9}$$

where Y = ADIN as percentage of DM
X = heating degree days $\geq$ 35C.

Thomas et al. (1982) described some of the variation in ADIN in silages and additional factors that contribute to its variation. Wood (1971) described the temperature in a silo as a function of the density reached within 3 days as

$$T = 70 - 1.2\ D \tag{10}$$

where T = degrees Celsius
D = wet density in pounds per cubic foot.

A density of 30 lb/ft^3 would give a temperature of 34C or minimize the risk of heat damage. Wood (1971) described the required filling rate in US tons of DM per day as a function of DM percentage and diameter of silo in order to attain a density of 25 lb/ft^3 (table 2). A ten-unit increase in percentage DM essentially doubles the required tons of DM. The required tons of DM changes functionally with diameter as does surface area, i.e., as the squared power. A diameter increase of 1.5 increases required tons of DM by 2.25; a diameter increase of 2.0 increases required tons by 4.0.

Importance of Silo Size and Filling Rate

Very large silos limit the range of DM where good wilted hay-crop silages can be made (table 3). Increasing the silo height from 40 to 80 feet will increase the minimum DM required to avoid seepage from 30 up to approximately 34%

Table 4.--Effect of slow filling 24-foot-high silos with high-moisture grass legume herbage[a]

Criteria	One-day filling	Five to eight-day filling
Dry matter recovery (%)	83.0	77.0
Dry matter intake (lb/cow/day)	13.7	12.7
Milk production (lb/cow/day)	28.7	27.6
Weight gain (lb/cow/day)	1.1	0.9

[a] Miller and Clifton (1962).

Table 5.--Effect of propionic acid treatment on hay-crop silages at 50 to 69% dry matter[a]

Criteria	0% propionic acid[b]	0.8% propionic acid[b]
Top spoilage (%)	5.4	0
Fungal counts (10 /g DM)	2.66	.56
Degree days $\geq$ 35C	322	154
Acid detergent-insoluble N (% DM)	.40	.37

[a] Yu and Thomas (1975).

[b] Percentage of fresh herbage.

Table 6.--Temperatures of corn silage with 32% dry matter after removal from the silo[a]

Silage	Hours after removal	
	0	24
	--------(C)--------	
Untreated	25.6	46.5
Ammonia-treated[b]	20.8	19.3

[a] From Soper and Owen (1977).

[b] ProSil.

(Waldo, 1977). Assuming that 30 tons of DM can be harvested per day the maximum DM required to prevent heat damage decreases from 60 to 46% when changing from a diameter of 16 to 32 feet. The acceptable DM range is decreased from 30 units to 12 units. If the forage dries at 4 percentage units per hour (Waldo, 1977), then the time available for making good silage from a cutting is 7.5 hours in the small silo and 3 hours in the large silo (table 3). Large silos increase the management difficulty of making wilted hay-crop silages.

Miller and Clifton (1962) compared slow filling over 5 to 8 days with rapid filling over a single day in 24-foot-high silos using high-moisture grass legume mixtures (table 4). Slow filling reduced DM recovery by 6 percentage units. Dry matter intake and milk production each decreased about 1 lb/cow/day. Weight gain decreased .2 lb/cow/day.

Additives to Control Heating and Aerobic Deterioration

Aerobic deterioration can occur during wilting in the field and the initial aerobic process of using up trapped oxygen, and from air infiltration during storage and aerobic exposure during removal (McDonald, 1981). Aerobic deterioration in grass silages and presumably legume silages, is primarily caused by the top-growing (or pellicle) yeasts and molds (McDonald, 1981; Honig and Woolford, 1980; Ohyama et al. 1980). Heat damage in hay-crop silages is probably most practically controlled with propionic acid (Yu and Thomas, 1975; Honig and Woolford, 1980) at .4 to 1.0% of fresh forage weight. Addition of propionic acid at .8% of fresh weight decreased top spoilage, fungal counts, heating degree days, and ADIN (table 5). A 67% mixture of propionic acid, as Chemstor III, is approved under EPA Temporary Permit No. 11558-EXP-IG at 1% of fresh forage weight.

Aerobic deterioration in corn silages is primarily caused by yeasts and bacteria (McDonald, 1981; Honig and Woolford, 1980). Ammonia is probably a more practical additive for controlling heating and aerobic deterioration in corn silages because they are low in nitrogen for most feeding situations (Honig and Woolford, 1980). Soper and Owen (1977) found ammonia in solution very effective for improving stability of corn silage (table 6). The surface temperature of treated corn silage during feeding was nearly 5C cooler and the temperature 24 h after removal was about 26C cooler than untreated corn silage. Honig (1975) found ammonia in solution to be more effective than urea for controlling heating in aerobic deterioration. Anhydrous ammonia is approved by FDA for addition to corn silage at .35% of fresh forage weight (CFR, 1980a).

PROBLEMS OF WET SILAGES AND ADDITIVES

Direct Acidification with Formic Acid

Hay-crop silage that is too wet to make good silage may be helped with direct acidification (Waldo, 1978). Weissbach et al. (1977) indicated that a wider DM range is available for making a stable silage if formic acid is used when the DM is between

$$29 - 8\ (S/BC) \leq \%\ DM \leq 45 - 8\ (S/BC) \qquad (11)$$

where S and BC are as defined for equation 3 (figure 6). According to equation 11, the alfalfa in table 1 with S/BC = .8 should make stable silage with formic acid at DM concentration as low as 23%. Weissbach et al. (1977) calculated the acid requirement from

$$kg = \%\ DM\ (.662 - .0135\%\ DM - .108\ (S/BC)) \qquad (12)$$

where kg = kg of 85% formic acid/1000 kg of fresh forage and S and BC are as defined for equation 3. According to this equation, alfalfa with S/BC = .8 and % DM = 25 would need 6.0 kg of formic acid/1000 kg. Formic acid is the most widely used additive in the world, with an estimated 25 million tons, or 30%, of the total hay-crop silage in northern Europe being treated (Drysdale and Berry, 1980). Formic acid is approved by FDA for use at 2.25% of forage DM (CFR, 1980b). Our 1982 cost for 90% formic acid in drum lots was $.3875/lb. A new process for making formic acid from carbon monoxide has been developed (Czaikowski and Bayne, 1980) and is expected to help hold down price increases.

Protein Preservation with Formaldehyde

Additional protein can be preserved in wet hay-crop silages with the use of formaldehyde (Waldo, 1978) at about .5% formaldehyde in forage DM or at about 3 g formaldehyde/100 g crude protein in the forage (Wilkinson et al., 1976). In three recent experiments, mixtures of formic acid and formaldehyde on five treated direct-cut alfalfa silages have produced daily gains of 976 g (± 72 as a standard deviation) in Holstein heifers and steers weighing about 300 kg; one untreated direct-cut alfalfa silage produced a daily gain of 471 g. These are excellent rates of gain and they are very consistent. Our 1982 cost for 37% formaldehyde in drum lots was $.1625/lb. Based on our 1982 costs this 1:2 formic acid formaldehyde would cost $2.375/ton of fresh weight of ensiled herbage. Research on formaldehyde is continuing at Beltsville in an effort to get eventual approval for ensiling.

Protein Preservation with Ammonia

Anhydrous ammonia is a promising additive for corn silage. Ammonia is a strong inhibitor of protein degradation in corn silages. Insoluble nitrogen was essentially completely recovered in corn silages from 28 to 44% DM when .4% anhydrous ammonia was added (Waldo et al., 1980). The energetic efficiency of ensiling was also increased as evidenced by an increased recovery of energy and residual sugar even though more lactic acid was produced in the treated silages (Goering and Waldo, 1980; Waldo et al., 1980). In 1981, our cost for anhydrous ammonia was $.1558/lb.

Substrate Addition

The addition of fermentable substrates is a possibility for making better silages. Molasses or other sugar sources may be used, but they do little to improve the extensive losses (Watson and Nash, 1960) or the reduced dry matter intake (Demarquilly and Jarrige, 1970) of untreated, direct-cut hay-crop silages. Grains or starch sources may be added, but silage fermentations require amylases or malt (Nilsson, 1969) to break down starch prior to fermentation. Corn meal, without amylases, added at ensiling of alfalfa changed the DM and BC and increased energy recovery; daily gain, intake, economics and management flexibility were better when corn was added at feeding (Goering, 1978).

Additives for Increasing Efficiency of Fermentation

Many microbiological additives have been tried in efforts to establish a more efficient fermentation producing lactic acid. The experience at Beltsville is primarily with the inoculant Sila-Bac. In studies with orchardgrass and corn silages in large silos, only daily gain by dairy heifers was improved in treated orchardgrass silages (Goering and Waldo, 1978) and no other differences in composition, recovery, or digestibility were observed; no differences were observed in corn silage. In studies of alfalfa, orchardgrass, and corn silages in small silos, treatment improved the digestibility of alfalfa but not the others (Waldo and Goering, 1976). Consistent and repeatable differences were not observed in these four experiments. Wilkins (1980) concludes that the primary problem in Britain is a shortage of fermentable material rather than appropriate bacteria.

Possible Future Additives

Three other promising additives for hay-crop silages are receiving some attention in England. Sodium acrylate is soluble, nonvolatile, noncorrosive, and more effective than formic acid for controlling aerobic deterioration (Wilkins,

1980). Ammonium tetraformate has lower vapor loss (and thus less fume problems) and is less corrosive than formic acid but is more expensive (Drysdale and Berry, 1980). Both of these additives are possible alternatives to formic acid. Glutaraldehyde (Wilkins, 1980) might substitute for formaldehyde as a preserver of protein during ensiling.

SUMMARY

Good, stable silage fermentations are limited by the pH and DM. High-DM silages require less pH reduction than low-DM silages. The major substrate for lactic acid production is sugar or water-soluble carbohydrate. The amount of acid required for pH reduction is dependent on the buffering capacity of the ensiled material. The efficiency of acid production can vary from a production of largely lactic acid to a mixture of lactic acid and weaker acids down to largely alcohol. Wilting is widely used to improve hay-crop silages. Wilting introduces a dependence on the weather and may produce excessively dry herbages for ensiling. Excessively dry herbages incur more heating and aerobic oxidation. Aerobic oxidation is best controlled with propionic acid in hay-crops and ammonia in corn silages. Formic acid is most commonly used for direct acidification of hay-crop silages. Protein degradation is best controlled with formaldehyde in hay-crop silages and ammonia in corn silages. Energy or substrate additives do not decrease storage losses or improve intake. Microbiological additives have not consistently improved the efficiency of the fermentation.

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SMALL GRAIN AND HAY SILAGES FOR MILK PRODUCTION IN VIRGINIA

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Animal production in this region is a system of converting home-grown feedstuffs and marketing them as a human food source. Summarization by Waldo and Jorgensen (1981) shows that hay and pasture utilization by milking cows has decreased somewhat over the past 15 years on a percentage basis. This has been compensated for by modest increases in other harvested forages (silage) and large increases in concentrate consumption.

Silage utilization by dairy cows in Virginia peaked in the mid-70's. Concentrate consumption has leveled out, and hay intake has increased significantly over the same period of time. This is summarized in the following table.

Feed Summary, Virginia
Dairy Herd Improvement Association

Feeding Program (Per Cow)	1971	1976	1980	1981
Pounds silage & other succulents fed	16,700	18,100	17,600	17,100
Pounds hay fed	1,500	1,200	1,400	1,700
Pounds grain fed	4,600	5,000	5,300	5,300
Days on pasture	135	133	125	104

Source: Patterson 1981.

Over the years, the objectives of our dairy nutrition research program has involved extensive evaluation of forages. Part of this has involved getting descriptive values for forages in order to define experimental conditions. In many cases, we have made direct comparison of forages.

CORN SILAGE AS OUR STANDARD

Much of our research has involved corn silage. This is logical, since it has played such a central role as a feedstuff for

dairy cattle in Virginia as well as in other states. Corn silage and technology associated with producing and feeding it have made a major positive impact on dairy production. With corn silage as a basis, we developed a concept of ration fiber as an energy index and developed a computerized ration balancing procedure. Many of the developments with fiber and rations in corn silage have been generally applied to other forages and appear successful in field applications.

Taking into account the quality factor in forages when balancing dairy rations promotes practices in growing, harvesting, and storing forages that maximizes quality. In the mid-60's, extension recommendations were 1 unit of 18%-20% crude protein concentrate per 3 units of milk when corn silage was the forage. This was a "safe" recommendation in that it usually met the energy and protein needs of the lactating cow regardless of corn silage quality. However, by having an inverse indicator (fiber) of corn grain yield (energy) in silage, different supplementations are indicated, making it not only prestigious to have excellent quality silage, but also economically advantageous. Table 1 shows rations balanced for various forages and how costs might be affected.

Corn silage was and still is the primary source of forage and energy for lactating dairy cows in Virginia. Corn is still the recommended crop to grow on especially suitable productive land. Recommendations are changing and changes are occurring in the forages fed.

We are not seeing decreases in the number of corn silage samples analyzed in the forage testing laboratory, but percentage wise, corn silage seems to be declining slowly in proportion. The principal increases have occurred in rye and alfalfa silages and alfalfa hay.

BARLEY

In late 60's and early 70's we demonstrated that soft-dough direct-cut barley silage was nearly equal to corn silage for lactating cows (Polan et al. 1968, and Rock et al. 1974). When cut in the bloom stage or later, the soft-dough stage was optimal for quantity and quality. Beyond soft-dough, the plant becomes very fibrous, and intake and digestibility are markedly reduced. Growth of barley to be harvested at soft-dough was recommended, and barley for silage increased modestly in the mid-70's. In later work (Snyder et al., 1979) we showed that direct-cut barley silage was more digestible than that wilted to 40% and 50% dry matter. However, milk production was highest with 40% dry matter silage when supplemented with adequate protein. Since then, barley silage has decreased relative to other forages.

Table 1.--Comparison of rations for milk production

Item Reported	Silage Rye	Silage Rye	Silage Alfalfa	Silage Alfalfa	Silage Corn
Silage Content					
Dry matter (%)	40.0	40.0	50.0	50.0	39.0
Crude protein (%)	20.0	14.0	22.0	18.2	7.8
Acid detergent fiber (%)	30.0	38.5	34.0	41.5	29.5
Ration					
Silage (%)	83.5	66.5	57.3	50.0	85.7
Corn grain (%)	10.3	15.3	13.8	18.8	2.1
Soybean meal (%)	--	2.74	--	--	7.9
Dicalcium Phosphate (%)	0.32	0.29	0.26	0.27	0.38
Limestone (%)	0.21	0.28	--	--	0.17
Trace-mineral salt (%)	0.18	0.16	0.08	0.09	0.10
Nutrients Supplied					
Dry matter intake (lb)	43.0	42.9	40.9	41.7	43.0
Acid detergent fiber (%)	23.9	25.3	24.7	26.1	24.7
Crude protein (%)	17.6	14.6	18.4	15.0	14.5
Ca (%)	0.61	0.62	0.96	0.85	0.61
P (%)	0.46	0.46	0.48	0.47	0.46
Net Energy (Mcal/da)	30.0	30.0	30.0	30.0	30.0
Feed Costs ($) 1982					
Cow/day	2.47	2.48	2.74	2.64	2.50
Forage/ton	40	30	60	50	30
Corn/ton	140	140	140	140	140
Soybean meal/ton	250	250	250	250	250

Rations were calculated for a group of 100 cows: average weight, 1,300 lbs; average milk production, 60.0 lbs/day; average fat test, 3.7%.

WHEAT

There has always been some interest in wheat for spring ensiling. With the introduction of 'Blue Boy' wheat, interest picked up, but no significant impact was felt. Tennessee workers (Baxter et al. 1980) concluded that boot-stage wheat silage was unpalatable relative to corn or alfalfa silage. Dry matter and acid-detergent-fiber digestibility of wheat silage were inferior to those of corn silage.

AUSTRIAN WINTER-PEA WITH BARLEY

Austrian winter-pea, a winter-hardy legume, was evaluated as a forage crop for dairy cows (Boman and Polan 1980). In plot work, yields and protein content led us to believe it could be an asset as a spring-cut forage. Growth was lush, and some pods has formed when barley reached the soft-dough stage. Hence, it was seeded with barley, so that barley would support it (Table 2). Barley alone yielded more dry matter, but protein was greatest when the pea was present. However, barley grain developed less when the pea was present. Dry matter intakes and milk production were less in 1979 and 1980 for barley and pea compared to barley alone. Barley and pea had to be wilted, which was a slow process. Also, large increases in fuel were required to chop the vine-wound windrows. Therefore, barley was the preferred forage.

RYE

The small-grain silage of most importance now in Virginia is rye. This may be surprising, because rye is harvested in a relatively immature state and should be wilted. However, we have unpublished data on prebloom direct-cut rye silage that show exceptional dry matter intake and milk production in Holsteins.

Why should rye become more important for silage than the other small grains? First, rye is more winter-hardy. Second, it can be removed earlier and not compete with time of corn planting. The practice of allowing regrowth for 7-10 days before spraying prior to corn planting is gaining acceptance. This apparently allows adequate mulch and is not excessive relative to mechanical difficulties for sod-planting. Third, rye is fairly concentrated in protein, thereby reducing the need for purchased protein. Rye averaged 12.6% crude protein (on a dry basis) in 1969-70, but increased to a high average of 15.1% in 1980.

HAY-CROP SILAGES

With respect to ensiled perennials, our university has received for testing some grasses, a significant number of alfalfa-orchardgrass samples, and 6.2% of all samples as alfalfa silage (alfalfa hay nearly the same during 1979-80). Alfalfa useage has increased considerably over the past 10 years. We have

speculated that the upward trend in alfalfa corresponds to slight declines in corn silage. Corn has become more expensive to grow, and yields must be high to provide profitable returns.

Recent droughty years have favored alfalfa because of less gamble on marginal upland soils. A chemical-weed-insect problem has developed in continuous corn ground that alfalfa may help correct. Furthermore, there is a greater awareness of erosion. Both nitrogen fertilization and protein costs are high. Harvestore programs undoubtedly have some positive influence on alfalfa usage. Currently, Virginia has about 800 Harvestores, nearly double 5 years ago.

In contrast to small-grain silage, alfalfa production is competitive with corn for space and involves a conscious decision of reallocation of land usage. Generally, our calculations have shown that it is economically unsound to grow and feed alfalfa for milk production as a forage replacement for corn silage in Virginia. There are justifiable exceptions, such as when the yield of alfalfa is much better than average. Alfalfa-based rations result in more costly rations, as shown in Table 1. Energy still accounts for 65%-70% of the cost of a dairy cow ration; therefore, we have to feed more concentrates with than with corn silage. For alfalfa to compete with corn silage, it must either be less costly per ton to produce or yield a higher energy concentration. With high-quality alfalfa (22% crude protein) as the only forage source, dietary protein is usually unnecessarily high, which results in waste.

SUMMARY

In Virginia, corn silage has served as the standard forage for dairy rations. With proper ration supplementation, it has served the industry well. Small-grain silages have had a minor but important role in providing forage. Rye has emerged the leader, probably because of winter-hardiness and early harvest coordinated with corn planting. With improved varieties and chemicals for alfalfa weevil, improved storage facilities, and a personal desire to grow high-quality protein, alfalfa acreage is increasing. Therefore, it is becoming more competitive economically, but yields must be very high to have an advantage over corn silage.

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Table 2.--Yields and composition of barley and barley-pea silage and milk production responses to the ensiled forages

	Barley	Barley-Pea
Milk (kg/d):		
Low Protein	39.2	33.6
High Protein	44.5	34.6
Yields (kg/ha)	6305	6035
Protein (kg/ha)	534	855
Weight of 56 heads (g)	59.7	48.4
Dry Matter (%)	29.3	41.1
Protein (%)	8.8	14.1
Acid detergent fiber (%)	36.3	40.6

SOYBEANS-GRAIN SORGHUM VS. CORN FOR SILAGE FOR LACTATING COWS

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Dairymen throughout the upper South have been trying various crops that may fit into a double cropping system in order to increase the productivity per acre. Small-grain silages have been used extensively on some dairy farms. Under some cropping plans they are harvested too late to follow with corn for silage. As a result, soybeans and grain sorghum have been suggested as an alternative that may fit better due to a shorter growing season than a full-season corn. The use of soybeans and grain sorghum is not a new practice since this combination has been harvested for silage on dairy farms in years past. The practice of harvesting this mixture as low-moisture silage has recently been suggested for use in oxygen-limiting structures.

Research at the University of Tennessee was designed to evaluate the yield per acre, chemical composition, dry matter intake and milk production potential of soybeans-grain sorghum and corn harvested as silage for lactating dairy cattle.

Data have been collected for three years at the Dairy Experiment Station (USDA-University of Tennessee). Lee 74 soybeans and Dekalb C 42A grain sorghum (non-bird resistant) were seeded at a rate of 2 bushels/acre and 15 lbs./acre respectively. Corn (Pioneer 3147 or FFR 929W) was seeded at 20 lbs./acre. Fertilizer application was at the recommended rate for each crop based on soil test. The planting and harvesting dates are presented in Table 1. Note that days from planting to harvest was about 122 days for corn silage compared to 79 days for the soybean-grain sorghum harvested in flower or bloom stage to the soybean. Difficulty has been encountered in determining the time to cut the second stage of soybeans-grain sorghum due to advanced maturity of the sorghum prior to a significant seed set in the soybean plant. One other problem that has been encountered is the difficulty in finding applicable herbicides for effective weed control. The percent of the dry matter from each source is presented in Table 2.

Table 1.--Planting and harvesting dates for corn and soybean-sorghum

	Planted	Harvested	Days To Harvest
Corn			
1979	May 1	Sept. 1	124
1980	April 22	Aug. 14	116
1981	April 3	Aug. 12	127
Soybean-Sorghum-Flower			
1979	June 9	Aug. 21	74
1980	May 28	Aug. 12	77
1981	May 4	July 28	85
Soybean-Sorghum-Pod			
1979	June 9	[a]	--
1980	May 28	Aug. 26	91[b]
1981	May 4	Sept. 9	128[c]

[a]Destroyed by Hurricane Frederick.
[b]Days less due to drought and lack of seed set.
[c]Days longer due to delayed seed set-grain sorghum-very mature-seed loss.

Table 2.--Component dry matter yield of the soybean-sorghum silage

	% of dry matter yield		
	Soybeans	Sorghum	Weeds
Flower Stage			
1979	33.7	63.3	3.0
1980	23.5	64.9	11.6
1981	36.8	56.2	7.0
Pod Stage			
1980	33.3	38.0	28.7
1981	60.5	38.3	1.2

Table 3.--Silage and dry matter yields for three years data

	% Dry Matter	Tons/Acre Silage Yield (30% DM)	DM Yield
Corn Silage			
1979	34.2	16.9	5.1
1980	38.8	15.5	4.7
1981	32.5	22.5	6.8
Soybean-Sorghum-Flower			
1979	33.1	10.4	3.1
1980	34.6	11.6	3.5
1981	25.7	12.5	3.8
Soybean-Sorghum-Pod			
1980	44.4	12.5	3.8
1981	36.7	12.7	3.8

Table 4.--Chemical composition of silages at feeding

	DM Basis Crude Protein	ADF	AIL
		%	
Corn Silage			
1979	9.2	26.6	2.7
1980	8.3	33.6	3.5
Soybean-Sorghum-Flower			
1979	16.2	41.7	7.0
1980	11.9	42.5	6.5
Soybean-Sorghum-Pod			
1980	11.4	41.5	6.7

Table 5.--Silage appraisal by the Tennessee silage score card

Criteria	Corn				Soybean-Sorghum					
	Possible Score	1979	1980	1981	Possible Score	Flower[b] 1979	Flower[b] 1980	Flower[b] 1981	Pod[b] 1980	Pod[b] 1981
Grain Content[c]	40	--	30	32	--	--	--	--	--	--
Stage of Growth	--	--	--	--	40	33	31	34	27	29
Color	12	--	8	8	12	9	9	9	8	9
Odor	28	--	23	23	28	26	25	23	24	25
Moisture	10	--	9	9	20	18	18	17	17	18
Chop	10	--	8	9	--	--	--	--	--	--
Total Score	100	--	78	81	100	86	83	83	76	81
Rating	--		Fair	Good	--	Good	Good	Good	Fair	Good

[a]1979 Corn silage was not scored.
[b]Stage of maturity of soybeans.
[c]Visual estimate.

All silages were stored in 10' x 40' upright stave silos.

Less weed infestation in 1981 was due to use of land with limited application of liquid manure slurry prior to seeding.

Silage and dry matter yields are presented in Table 3. Corn silage yielded an average of 5.5 tons of dry matter per acre compared to an average of 3.6 tons/acre for the soybean-sorghum combination.

Chemical composition data in Table 4 indicate that corn silage was lower in crude protein, acid detergent fiber and acid insoluble lignin than the soybean-sorghum silages. Comparable yields of protein/acre were obtained when dry matter yields and crude protein composition were considered for the two crops. This does, however, indicate that when feeding the two silage types less percent protein is needed in the grain mixture when supplementing the soybean-sorghum silage.

In each of the three years, ten lactating Jersey cows (40-90 days postpartum) were assigned to each treatment. Grain was fed at the rate of 1 lb. grain for each 4 lbs. of 4% fat-corrected-milk (FCM). Cows fed corn silage were fed a grain mixture containing an average of 19.7% crude protein (DM basis), whereas those cows fed soybean-sorghum silage received a grain mixture that averaged 13.7% crude protein (DM basis).

Visual appraisal scores were made by Professor Joe Burns using the Tennessee Silage score card. These data are in Table 5. Note that with the exception of corn silage and pod stage soybean-sorghum silage in 1980 all silages scored in the good category based on appropriate descriptive terminology.

Intake, milk production and composition and body weight change data are presented in Table 6. Each year the total dry matter intake of cows fed the soybean-sorghum silage harvested in the flower stage was significantly lower ($P<.05$) than intake of cows fed corn silage. There was no significant difference in dry matter intake of cows fed pod stage soybean-sorghum silage in 1980 compared to corn silage but was significantly lower in 1981. When comparing forage dry matter intake for all three years, cows fed flower and pod stage soybean-sorghum silage consumed 88 and 92 percent respectively as much as cows consuming corn silage. This reduction in forage intake is due to the higher fiber content of the two soybean-sorghum silages. Milk production differences between silages reflect the differences in dry matter intake. Milk production for cows fed the soybean-sorghum silages was 90 percent of that produced by cows fed corn silage. Body weight changes of cows fed the three silages also reflect the differences in dry matter intake.

In summary, the use of soybeans and grain sorghum may provide an option for the dairyman interested in double cropping some

Table 6.--Dry matter intake, milk production and weight change summary for three years data

	D.M. Intake (%B.W.)	Milk (Lbs.)	FCM (Lbs.)	B.W. Change
Corn Silage				
1979	3.16[a]	36.8[a]	41.1[a]	+.80[a]
1980	3.25[a]	37.3[a]	40.1[a]	+.37[a]
1981	3.54[a]	38.6[a]	40.7[a]	+.52[a]
Soybean-Sorghum-Flower				
1979	2.88[b]	33.8[b]	37.0[b]	+.29[b]
1980	2.91[b]	33.3[b]	35.9[b]	+.08[b]
1981	2.96[b]	35.1[b]	39.0[ab]	+.31[b]
Soybean-Sorghum-Pod				
1980	3.16[a]	33.2[b]	36.7[b]	+.18[ab]
1981	3.10[b]	34.8[b]	36.3[b]	+.41[ab]

[ab]Values within years with different superscripts are significantly different ($P<.05$).

of his land. Also, the use of this crop may be one of several options as insurance against drought losses from corn silage. Some dairymen feel that soybeans-grain sorghum can be planted more economically than corn; however when all costs are included this is not necessarily the case when compared on cost per ton of dry matter. Data have also shown that milk production of cows fed soybeans-grain sorghum is about 90% of milk produced by cows on corn silage. Reduced intake of energy due to a higher fiber silage is the main reason. To obtain comparable yield of milk, more grain must be fed per day to cows consuming soybean-sorghum silage.

ANIMAL WASTE UTILIZATION AS SILAGE

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Animal wastes are valuable resources if managed properly. Approximately 112 million tons of waste, dry basis, were produced in 1974, of which 52 million tons were collectable (Van Dyne and Gilbertson, 1978). The distribution of the amounts by class of animals is shown in table 1. A large part of the wastes are from animals managed under intensive systems, frequently close to municipalities, lakes and streams. Unless the wastes are judiciously handled, they may be a source of contamination to water supplies and a risk to human health and comfort. However, the wastes contain nutrients which may be used by plants and animals.

Animal wastes have been used mainly as fertilizer but economic studies indicate that at least under some economic conditions the plant nutrient value of the wastes is not high enough to justify the cost of hauling and spreading (Wadleigh, 1968). Furthermore, land disposal or use as fertilizer may be difficult for large concentrated animal production systems.

Wastes from different species of animals appear to have nutritional value for certain phases of animal production. Feeding of these wastes appears to be a more economically feasible approach than disposal or using as fertilizer. The wastes vary in nutritional value but it appears that use could be made of these for feeding. Some of the more nutritious wastes may be used as supplementary sources of protein and minerals, whereas other low-protein, high-fiber wastes may be used as roughage substitutes for dry cows and stocker cattle, or to supply roughage in fattening rations. Processing of wastes is important for destruction of potential pathogens, improvement of storage characteristics and maintenance or improvement of palatability. Processes which have been used successfully include heat drying, autoclaving and chemical treatment. However, ensiling alone or with other ingredients looks especially attractive due to the low requirement for fossil fuel.

Table 1.--Livestock and poultry waste production in the United States in 1974[a]

Class of animal	Thousands of tons of dry waste Production	Collectable
Beef cattle (range)	52 057	1 897
Feeder cattle	16 428	16 000
Dairy cattle	25 210	20 358
Hogs	13 360	5 538
Sheep	3 796	1 700
Laying hens	3 374	3 259
Turkeys	1 251	983
Broilers	2 086	2 434[b]
Total	111 562	52 169

[a]Van Dyne and Gilbertson (1978).
[b]Includes litter.

Information has been obtained on the nutritional value of poultry, cattle and swine waste. Nutrient content of caged-layer waste, broiler litter, steer waste, cow waste and swine waste is shown in table 2. The rank order of the nutritional value of animal wastes as feeds for ruminants is as follows: excrements of young poultry, deep litter of young poultry, hog feces, excrements of laying hens, hog and layer dung solids and excrements of cattle (Koriath, 1975).

Performance of animals fed animal wastes has been satisfactory, if the level of waste has been limited to meet the nutrient requirements of the animals. Generally, similar performance was recorded for cattle and sheep fed diets containing animal waste and control diets (Smith and Wheeler, 1979). As shown in table 3 rate of gain of steers fed a fattening mixture containing 25% peanut hull or wood shaving broiler litter plus 2.2 lb of long hay per day was similar to that of steers fed a control mixture and long hay (Fontenot *et al.*, 1966). Feed efficiency was in favor of the litter-fed cattle.

ENSILING ANIMAL WASTES

In order to obtain good ensiling sufficient soluble carbohydrates must be present and dry matter content must be optimum. Usually, mixing the waste with other ingredients is desirable.

Poultry Litter

In order to obtain good fermentation for broiler litter ensiled alone, the moisture level should be approximately 40%

Table 2.--Nutritional value[a] of animal wastes

Item	Kind of waste				
	Broiler litter[b]	Dehydrated caged layer waste[b]	Steer waste[b]	Cow waste[b]	Swine waste[c]
Crude protein, %	31.3	28	20.3	12.7	23.5
True protein, %	16.7	11.3		12.5	15.6
Digestible protein, %	23.3	14.4	4.7	3.2	
Crude fiber, %	16.8	12.7			14.8
Ether extract, %	3.3	2		2.5	8.0
NFE, %	29.5	28.7		29.5	38.3
Dig. energy (ruminants), kcal/g	2440	1884			
Metab. energy (ruminants), kcal/g	2181				
TDN (ruminants), %	59.8	52.3	48	45	
Ash, %	15.0	28	11.5	16.1	15.3
Calcium, %	2.4	8.8	0.87		2.72
Phosphorus, %	1.8	2.5	1.60		2.13
Magnesium, %	0.44	0.67	0.40		0.93
Sodium, %	0.54	0.94			
Potassium, %	1.78	2.33	0.50		1.34
Iron, ppm	451	0.2	1340		
Copper, ppm	98	150	31		63
Manganese, ppm	225	406	147		
Zinc, ppm	235	463	242		530

[a]Dry basis.
[b]Adapted from Bhattacharya and Taylor (1975).
[c]From Kornegay et al. (1977).

Table 3.--Feedlot performance and carcass quality of steers fed broiler litter (123 days)[a]

	Broiler litter rations		
	Wood shavings litter[b]	Peanut hull litter[b]	Control ration
No. of steers	10	10	10
Av. weight data, lb			
Initial wt.	835	828	861
Final wt.	1180	1155	1213
Gain	345	327	352
Daily gain	2.81	2.65	2.87
Daily feed, lb[c]			
Mixture	26.2	26.3	29.8
Long hay	2.2	2.2	2.2
Total	28.4	28.5	32.0
Lb feed/lb gain			
Mixture	9.34	9.91	10.40
Long hay	0.79	0.84	0.78
Total	10.13	10.75	11.18
Av. carcass data			
Carcass grade[d]	10.6	10.0	10.8
Dressing %[e]	58.5	60.2	60.2
Loin eye area, sq. in	12.14	11.94	12.33
Fat thickness, in[f]	0.68	0.75	0.77

[a]Adapted from Fontenot et al. (1966).
[b]25% litter in fattening mixture.
[c]Salt and a mineral mixture of 3 parts defluorinated phosphate, 1 part limestone and 1 part salt were provided, in addition.
[d]Code: 9 - low good; 10 - average good; 11 - high good; etc.
[e]Based on final weight and warm carcass weight.
[f]Fat thickness over 12th rib.

(Caswell et al., 1978). Digestibility of proximate components and nitrogen utilization by sheep fed a ration containing litter ensiled with 40% moisture were similar to those for sheep fed a soybean-meal-supplemented ration. Rate of gain of dairy heifers was increased by substituting 15 or 30% ensiled turkey litter dry matter for corn silage (Cross and Jenny, 1976).

Adding whey to increase the moisture content in ensiled broiler litter was beneficial in lowering the pH if the broiler litter had been deep-stacked previously, but had no beneficial effect when the litter was ensiled immediately after removal from

Table 4.--Composition of corn-broiler litter[a]

Silage			Composition of dry matter				
Maturity[b]	Treatment	Dry matter	Crude protein	Ether extract	Crude fiber[a]	NFE[a]	Ash[a]
		%	%	%	%	%	%
1	Control	24.18	8.84	1.75	23.95	60.92	4.54
1	Urea[c]	23.45	14.56	1.94	24.25	54.06	5.19
1	Litter-15[d]	27.07	12.47	2.15	24.18	54.69	6.52
1	Litter-30[d]	31.63	15.79	2.64	23.75	49.19	8.63
1	Litter-45[d]	37.07	18.81	2.70	24.15	43.68	10.66
2	Control	36.60	7.59	2.05	21.15	65.82	3.39
2	Urea[c]	36.66	11.46	1.81	21.54	61.73	3.46
2	Litter-15[d]	40.51	10.64	2.23	22.43	59.23	5.47
2	Litter-30[d]	44.16	14.46	2.16	22.22	53.11	8.05
2	Litter-45[d]	50.26	17.50	2.64	22.71	47.89	9.26

[a]Adapted from Harmon _et al_. (1975a).
[b]Dry matter of corn forage was 25 and 36% for maturities 1 and 2, respectively.
[c].5% urea.
[d]Values refer to percent broiler litter, dry basis.

Table 5.--Feeding ensiled corn-broiler litter silage to fattening heifers 3-yr. summary[a]

Item	Corn silage No SBM[b]	Corn silage SBM[b]	Corn-silage-litter No SBM[b]	Corn-silage-litter SBM[b]
Initial wt., lb	500	509	514	509
Final wt., lb	795	900	922	918
Daily gain, lb	1.65	2.14	2.25	2.27
Feed/head/day				
Silage	18.4	22.7	26.8	26.1
Grain	7.9	6.5	8.6	6.7
Soybean meal		2.0		2.0
Feed/lb gain, lb				
Silage	10.9	10.3	11.7	11.2
Grain	4.7	2.9	3.7	2.9
Soybean meal		.9		.9
Carcass quality grade[c]	11.6[d]	11.5	12.4	12.6
Dressing %	58.0[d]	57.0	59.0	60.0
Loineye muscle area, sq in	9.62[d]	10.32	10.15	10.49
Backfat thickness, in	.60[d]	.70	.76	.79

[a]McClure *et al.* (1979).
[b]Soybean meal.
[c]Code: 11=high good; 12=low choice; 13=average choice, etc.
[d]Data for only last 2 years.

the house (Duque *et al.*, 1978). Caution should be used in adding water to litter prior to ensiling since at certain moisture levels the material has a gluey, sticky consistency which makes it difficult to handle.

As shown in table 4, mixing broiler litter with chopped whole-plant corn forage at levels up to 45% of the dry matter resulted in good ensiling with pH values of less than 5, and lactic acid levels similar to those in regular corn silage (Harmon *et al.*, 1975a). Incorporating broiler litter into the silage increased crude protein of the silage up to 18% for silage with 45% litter, dry basis. Voluntary intake by sheep of silage with 30% litter, dry basis, was about 70% greater than that of plain silage, and the nitrogen was efficiently utilized (Harmon *et al.*, 1975b). As shown in table 5 similar performance was obtained in finishing heifers fed corn-broiler litter silage containing 30% litter, dry basis, as for heifers fed corn silage supplemented with soybean meal (McClure *et al.*, 1979). Total concentrate intake was 1% of body weight.

Deep stacking broiler litter in a well ventilated building is a satisfactory processing method. Performance was similar for growing cattle fed broiler litter which was deep stacked or ensiled at 60% dry matter (Chester-Jones and Fontenot, 1981).

Caged Layer Waste

Most of the research with caged-layer waste has been with dehydrated material. Wet caged-layer droppings were ensiled with grass hay (Saylor and Long, 1974). Maximum acidity, lactic acid concentration, crude protein content and *in vitro* dry matter digestibility were observed with a ratio of 60 parts of caged-layer waste and 40 parts of hay. Silages with pH of 5 or below resulted from ensiling mixtures of alfalfa hay, corn grain, molasses and caged-layer waste treated with tannic acid or paraformaldehyde (Flipot *et al.*, 1975). Palatability of the silage with tannic acid was higher than that with paraformaldehyde.

Satisfactory ensiling was obtained with mixtures of caged-layer waste and sugarcane bagasse containing 40 or 50% waste (Samuels *et al.*, 1980). Lactic acid was over 5%, dry basis, for these mixtures. Good ensiling was achieved with mixtures of 60:40 and 40:60 caged-layer waste and ground corn stover (Moriba *et al.*, 1982). Lactic acid production was enhanced by addition of 10% dry molasses. Apparent digestibility of dry matter and crude protein was higher for silages containing 40:60 or 60:40 mixtures of waste and corn stover than ensiled stover (table 6).

Cattle Waste

Feasibility of mixing cattle manure with grass hay and ensiling the mixture was explored by Anthony (1969). The mixture consisted of 57 parts manure and 43 parts of grass hay and the ensiled material was termed "wastelage." Feeding a ration formulated to contain 40% wastelage and corn to steers produced rate and efficiency of gain similar to feeding conventionally formulated high-concentrate rations.

Ward *et al.* (1975) reported that a high-fiber silage produced by fractionation of feedlot manure, adding dry molasses and fermenting, had a TDN value of 60.2%, compared to 65.2%, dry basis, for corn silage when fed to cattle. This material contained 9.0% crude protein and 27.5% crude fiber, dry basis. Encouraging results were obtained from ensiling cattle manure with crop residue such as straw and corn stalks (Vetter and Burroughs, 1975).

Good ensiling with final pH values below 5 was reported with 70:30 to 30:70 mixtures of cattle waste and rye straw (Cornman *et al.*, 1981). Minimum pH and maximum lactic acid were reached after 1 week of ensiling. Apparent digestibility was higher for waste-straw silages than for straw ensiled alone. Addition of 4% sodium hydroxide prior to ensiling 60:40 mixtures of cattle waste and rye straw increased post-ensiling pH (Aines *et al.*, 1981). When sodium hydroxide was added the pH was 5.1 for silages made with waste from cattle fed a high-concentrate

Table 6--Apparent digestibility[a] of caged layer waste-corn stover silages by sheep[b]

Component	Corn[d] stover silage	Proportions of caged layer waste:corn stover[c]				SBM
		No additive		Molasses[h]		
		60:40 silage	40:60 silage	60:40 silage	40:60 silage	
Dry matter[i]	38.1[g]	50.3[e,f]	44.3[f,g]	52.4[e]	44.4[f,g]	.88
Organic matter[i]	40.8[g]	48.7[e]	47.5[e,f]	53.3[e]	46.1[e,f]	.97
Crude protein[i]	47.4[g]	68.8[e]	56.3[e,f]	71.7[e]	52.6[e,f]	
Ether extract[i]	12.7[f]	23.5[f]	24.0[f]	57.0[f]	30.0[e,f]	4.32
Neutral detergent fiber[i]	56.0	57.5	57.7	58.9	54.8	0.9
Acid detergent fiber[i]	61.0[g]	52.0[h]	70.1[e,f]	65.7[e,f]	72.0[e]	1.30
Cellulose[i]	73.5	73.5	73.9	76.3	73.1	1.14
Lignin[i]	50.8[e]	22.7[f]	37.8[e]	41.6[e]	44.1[e]	1.75

[a]Calculated by difference using values for ensiled mixtures plus basal and basal diet.
[b]Moriba *et al.* (1982).
[c]Values refer to caged layer waste:corn stover ratios, wet basis.
[d]Water added to corn stover to ensile at 60% dry matter.
[e,f,g]Means in the same row with different superscripts are different ($P<.05$).
[h]10% molasses, dry basis.
[i]Each value represents the means of 6 animals.

ration, but was 6.4 if the waste was from cattle fed a high-roughage ration. Addition of the alkali increased *in vitro* and *in vivo* dry matter digestibility. Satisfactory ensiling was achieved with mixtures of 60% cattle waste and 40% corn stover (Shorter *et al.*, 1981). Addition of sodium hydroxide prior to ensiling increased the pH to 5.9 or higher. Dry matter digestibility was higher for ensiled mixtures than for corn stover ensiled alone.

Swine Waste

Good ensiling was observed with mixtures of 30:70 to 70:30 swine waste and orchardgrass hay, wet basis (Berger *et al.*, 1981a). Digestibility values obtained with sheep indicated that the ensiled waste was digested to a greater extent than orchardgrass hay (Berger *et al.*, 1981b). Dry matter consumption by sheep of the mixtures which were tested (40 or 60% waste) was comparable to that of orchardgrass hay. The smell of these two silages was similar to that of good hay-crop silage with no swine fecal odor remaining. Berger *et al.* (1981a) also ensiled mixtures of swine waste and ground corn grain containing 20-80% swine waste, wet basis. Satisfactory ensiling occurred as measured by low pH values and high lactic acid levels. However, the smell of these silages was much more disagreeable than those made with mixtures of swine waste and orchardgrass hay. Digestion trials indicate that this material was utilized well by sheep, but palatability trials with silages containing 40 or 60% swine waste indicated that these mixtures were not very palatable to sheep (Berger *et al.*, 1981b).

QUALITY OF ANIMAL PRODUCTS

Feeding animal waste has not affected taste of the meat, milk or eggs (Fontenot and Jurubescu, 1979).

SAFETY CONSIDERATIONS

The only disease problem which has been shown to be caused by feeding animal waste has been copper toxicity in sheep fed broiler litter with high copper levels (Fontenot and Webb, 1975). The problem would not be severe in cattle since they are not as sensitive to high dietary copper. Beef females have been fed diets containing high levels of broiler litter with high copper levels alone and in combination with supplementary copper to add the equivalent of 200 ppm to the litter during the winter period since 1972; no deleterious effects were observed (Webb *et al.*, 1979).

Pathogenic Bacteria and Parasites

Animal wastes contain potential pathogens. Proper ensiling of animal waste appears to be effective in destroying patho-

gens (McCaskey and Anthony, 1979). It appears that a pH of 4 to 4.5 and a temperature of over 25°C are important for destruction of salmonella. Ensiling feedlot cattle manure and grass hay was effective in eliminating parasites (McCaskey and Anthony, 1979).

A potential risk from clostridia in waste-containing rations is suggested by an alleged botulism outbreak in Israel in cattle fed a concentrate with 10% poultry waste (Egyed et al., 1978). No relevant gross or histological lesions were found. The botulism organism (type D) appears to be endemic to Israel, as outbreaks have been reported in animals fed other types of feeds (H. Tagari, 1978 and S. Gordin, 1978, personal communications). Botulism in animals fed waste-containing rations has not been reported in other areas of the world.

Mycotoxins

Indications are that the mycotoxin problem is no greater in poultry litter than in feed (Lovett, 1972).

Pesticides

No evidence of pesticide accumulation in waste or in animal tissue from animals fed waste has been reported (Fontenot and Webb, 1975).

Minerals

Three heavy metals, arsenic, copper and selenium, are added to livestock and poultry rations, and three, cadmium, lead and mercury, are not added, but occur in feedstuffs. Feeding of arsenicals has been shown to result in increased liver arsenic in cattle after a 5-day withdrawal but the levels were much lower than the accepted safe levels (Webb and Fontenot, 1975). The other heavy metals have not been found to be sufficiently high to present a problem in cattle waste and poultry litter (Westing et al., 1977). Liver copper is increased by feeding waste with high copper levels (Webb and Fontenot, 1975).

Medicinal Drugs

Medicinal drug residues were present in broiler litter in variable amounts if the drugs had been included in the broiler diet (Webb and Fontenot, 1975). However, residues of the three drugs that were in litter, chlortetracycline, nicarbazin and amprolium, did not accumulate in edible tissue of finishing beef cattle after a 5-day withdrawal.

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ECONOMICS OF SILAGE SYSTEMS AND STRUCTURES

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INTRODUCTION

Forage production and storage accounts for 25 to 30 percent of the total costs of producing milk. Forage and concentrates together add up to 50 to 55 percent of the total costs. Approximately 40 percent of the variable costs of operating a dairy are related to forage production. Consequently, the development of a sound forage and feeding program is critical to the success of a dairy operation.

To maximize income the farmer must decide the proper forage or combination of forages and storage structures required to support milk production at the most profitable level. This process is complicated by a variety of factors including available land, labor, capital and management resources, personal preferences, herd size, production costs, yields, nutrient composition of each crop, erosion control requirements, storage costs, and price relationships between forage crops and between grain and forage. Therefore, the final decision must be made on an individual farm basis.

SILAGE SYSTEMS

Silage generally accounts for the majority of the forage in a dairy operation. Forage production cost estimates were developed for the crops identified in Table 1. Machinery and equipment costs were estimated from the University of Tennessee Crop and Livestock Budgets for 1982. Land rent either paid or given up was estimated at $50 per acre for cropland and $30 per acre for grass and clover hayland. No land rent was included for the small grain silage. Labor was charged at $4 per hour, and the interest rate was 16 percent.

Annual forage and feed requirements and costs estimates were developed for five basic silage systems (Baxter). The cow was assumed to weigh 1250 pounds and produce 13,000 pounds of 3.7

Table 1.--Estimated yield per acre and production costs per ton for major forages

Forage	Tons per acre	Costs per ton
Silage - 33% D.M.		
Corn	16.0	$20
Small grain	6.0	32
Soybeans-grain sorghum	11.0	29
Alfalfa	10.5	38
Alfalfa hay	3.5	99
Grass and clover hay	2.5	80

percent milk per year in a year-round drylot system of management. Feed requirements were included for the replacement animals including .58 acres of pasture and .53 tons of grass and clover hay on a per cow in the herd basis (Walch 1981). Silage yields and costs per ton were developed on the basis of 33 percent dry matter. Adjustments should be made for different moisture levels. Since the forages differed in energy and crude protein content, the rations were adjusted through the purchase of grain and protein supplement. High-moisture corn was not considered in the analysis. Annual feed costs for a

Table 2.--Estimated annual forage production costs, other ration costs, total costs per cow excluding forage storage, and acres of open land required for a 200-cow dairy

Silage program	Forage production costs per cow	Other ration cost per cow	Total feed costs excluding forage storage	Acres of open land for a 200-cow dairy
1. Corn	$432	$482	$ 914	361
2. Corn, small grain	486	497	983	306
3. Alfalfa	709	310	1,019	467
4. Corn, small grain, alfalfa	541	455	996	346
5. Soybeans-grain sorghum, small grain, alfalfa	622	419	1,041	379

200-cow dairy excluding forage storage ranged between $182,800 and $208,200. Other ration costs were the lowest with alfalfa

silage. However, alfalfa forage production combined with other ration costs resulted in a cost of $1,019 per cow. The corn silage and small grain double-cropped program had an increased estimated production costs of $69 per cow as compared to corn silage only. However, for the 200-cow dairy 55 additional acres of land were required for the corn silage only program. To evaluate the total system land availability and forage storage cost must be taken into account.

SILAGE STORAGE STRUCTURES

Annual storage costs were estimated for oxygen-limiting, upright concrete stave, concrete bunker, and earth trench silos. The initial investment for a 700-ton-capacity silo and unloader ranged from $2,842 for an earth trench structure to $98,276 for an oxygen-limiting silo (Table 3). Estimated investment

Table 3.--Initial investment for a 700-ton silo and unloader

Type structure	Initial investment	Investment per ton
Oxygen limiting	$98,276	$140
Concrete upright	28,550	41
Concrete bunker	12,307	18
Earth trench	2,842	4

per ton in the structure and unloader for a 450-ton oxygen-limiting silo was $157 as compared to $111 per ton in a 1000-ton silo. Investment per ton of capacity for a concrete upright was $47 for a 450-ton structure and $36 per ton for 1000 tons of initial capacity.

The silo structures have different potential rates of utilization. Based on 700 tons of initial capacity, total storage and feeding cost estimates according to the number of fillings per year ranged from $23.85 to $8.55 per ton.

Table 4.--Total storage and feeding costs per ton

Type	Number of fillings per year			
structure	1.00	1.25	1.50	2.00
Oxygen limiting	$23.85	$19.83	$17.17	$13.82
Concrete upright	10.60	9.37	8.55	---
Concrete bunker	12.90	---	---	---
Earth trench	14.67	---	---	---

The storage and feeding cost estimates included depreciation, interest, storage losses, maintenance, operating costs, and labor. The oxygen-limiting and concrete upright structures had an expected life of 20 years (Farmer 1980). The unloader was depreciated on the basis of 10 years of use. It was assumed the concrete bunker and earth trench silos had an expected life of 15 and 5 years, respectively. Storage nutrient losses will vary substantially by type of structure, management, and unique circumstances. The losses by silo type were assumed to be: 3 percent for oxygen limiting, 8 percent for concrete stave, 12 percent for concrete bunker, and 30 percent for earth trench silos (Logan 1975).

Initial investment requirements for forage storage and feeding facilities ranged up to over $200,000 for a 200-cow dairy. Annual forage storage costs for this system were estimated at $37,000. The determination of a forage production, storage and feeding system must be made on the basis of an evaluation of the unique farm resource situation. The cost estimates discussed earlier examined the forage issue from the standpoint of costs or profitability. The question must also be addressed from a cash flow standpoint. Instead of depreciation and interest, the lease or loan payment would replace these figures in a cash flow analysis. In some cases the results would be similar. In other situations, another $15,000 to $18,000 additional funds would be required per year for the additional payments on forage storage for a 200-cow dairy.

Forage production, storage, and feeding is a complex challenge for today's dairymen. Planning and implementing a sound forage program is essential for a financially successful dairy.

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OVERVIEW OF FORAGE AND LIVESTOCK IN VIRGINIA: DAIRY CATTLE

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Because the dairy industry in Virginia is dynamic, statistics that attempt to describe the industry or present situation must be viewed in the context of continued changes. The industry has changed dramatically in the last decade and will continue to adapt to new technology and economic situations. Virginia's dairy industry is reknowned for the progressive leadership provided by the dairymen and for breeding of quality dairy animals. Other attempts to describe what is typical of the dairy in Virginia only emphasizes its diverse nature.

The topography and climate of Virginia are conducive to quality forage production; however, forage programs by necessity vary considerably from region to region. Four production areas, differing in soil types and climate, generally dictate the types of forage programs for dairy farms. Dairy farms are found in the Coastal Plains at elevations slightly above sea level (adjoining the Coastal Waterway) and 3000 feet in the mountains of southwest Virginia. The growing seasons in the Tidewater area are typical of the southern tier of states. In the Burke's Garden area of southwest Virginia, growing seasons are not unlike that found in eastern New York.

Dairy herds are predominantly Holstein, but herds of Ayrshire, Jersey, Guernsey, and Brown Swiss of outstanding breeding are also found in the Commonwealth. More than 95% of the cows enrolled in dairy herd improvement (DHI) associations are Holsteins.

Milk is marketed primarily as Class I milk with 1972 Grade A dairies (Anonymous, 1982) operating in March, 1982. Estimates derived from extension surveys indicated approximately 1000 Grade C herds in 1978, but at present, only two manufactured milk receiving plants operate within Virginia.

Virginia dairy farms with herds containing from 70 to 130 cows represent a total investment of over $500,000 per farm (Edgar,

T., L. Chang, and C. Tyree, 1982 and Edgar, T., L. Chang, and C. Tyree, 1981). The average DHI herd numbers 82 cows (Patterson, W. N., 1981), with each cow requiring approximately 2.5 acres of open land and representing an investment of $5842 (Edgar, T., L. Chang, and C. Tyree, 1981). Estimates of replacement costs (excluding base but including equipment) in 1979 were $3775 per cow (Edgar, T., L. Chang, and C. Tyree, 1981). A major concern for the industry is that the average cow presently carries a debt load in excess of $2000 (Edgar, T., L. Chang, and C. Tyree, 1982).

On-farm sales of milk and cream emphasize the importance of the dairy industry to Virginia (Anonymous, 1981). Dairying leads other agricultural enterprises with on-farm sales of milk and cream (1979 data) of $262 million. These sales comprise 19.8% of the total gross farm receipts and did not include sales of breeding stock, cull animals, and bull calves. On-farm receipts traditionally have accounted for approximately 50% of retail sales. When one accounts for equipment and services affiliated with the dairy industry, the gross value to Virginia exceeds $1 billion annually.

Dairy cattle feeding is as diverse as other descriptions of the industry. Although group feeding is presently in vogue, one can find herds where cows are individually fed in stanchion barns and other herds with automated grain feeding regulated by computer. Production budgets prepared by the Virginia Department of Agriculture and Consumer Services (Anomymous, 1981) provide an insight for feed costs associated with milk production. Of the variable costs associated with production of Class I milk, feed costs were the major expense and accounted for 60 percent of the total. Forages accounted for 48 percent of feed costs, or $390 worth of forages were marketed for each dairy cow. Corn silage, the primary forage for dairy feeding, accounts for more of the total energy fed than all other stored forages combined. Grains and supplements, both produced on the farm and purchased, amounted to $419 per cow with protein and mineral supplements the most expensive purchased feeds. Supplements, generally purchased off the farm in Virginia, were estimated at $297 per cow, or more than the costs of corn silage in dairy rations.

In the past two decades, pasture feeding of lactating dairy cattle in Virginia has declined. This decline has been attributed to many factors, but the inability of dairymen to overcome the negative effects of hot, dry summers on forage quality must be considered as a foremost reason. Pasture remains as the least expensive feed input or TDN source for dairy cattle, and smaller herds still rely on pasture as a major feed source. The present economic situation of static prices and rising costs may dictate that more pasture be utilized in feeding lactating cows.

Descriptive data for Virginia DHI cows are shown in Tables 1, 2, and 3 (Anonymous, 1981, Ellmore, M. F., 1952-55, Patterson, W. N., 1981). Milk production per cow has increased and the increase is correlated with increased grain feeding and total feed intakes. Silage inputs shown in Table 2 are primarily corn silage; however, alfalfa, small grains, sorghums, and summer annuals are produced on some farms as the primary forage for the lactating herd. Forage-testing data indicate the continued production of high-quality corn silage and slight improvements in hay quality. The improvements in hay quality are attributed to increased production of alfalfa and the over-seeding of grasses with clovers.

Educational programs that will effect improvements in the quality of perennial forages are given a high priority in extension programs.

The technology associated with the production of milk is constantly changing, and these changes must be anticipated if research and extension programs are to remain relevant to the industry. Some trends or practices that are presently being adopted are listed. The listing is by no means complete, and it is not intended that the listing imply any particular order of priority or importance. These trends are considered as examples of changes that the dairy industry is making to adapt to new technology or manage more efficiently; in some cases, the industry is simply responding to economic pressures.

Continued improvement in the genetic potential of dairy cattle.

More dependence on scientific approaches to feeding. Mix wagons, on-farm computers, tailored concentrates, feed analysis, byproduct feeds, and mechanization of forage feeding are all included in this change.

Better rations for dry cows and replacement heifers to include more coarse fiber sources and improved mineral nutrition.

Less dependence on corn silage as a feed source.

Increased feeding of alfalfa or other perennials and small grains and summer annuals. More diversification, and the relatively new technology of no-till seeding are involved in this change.

Renewed interest in pasture improvement.

These are only some of the changes observed in Virginia, but the changes illustrate the dynamic nature of the dairy industry and emphasize that the industry is responsive to new knowledge and technology.

Table 1--Production in Virginia DHI herds.

Production	Year			
	1952	1961	1970	1980
Milk (lb/yr/cow)	8252	10,377	12,667	14,716
Fat (lb/yr/cow)	340	405	475	527
Milk fat (%)	4.1	3.9	3.8	3.6

Table 2--Feed inputs for dairy cattle.

Feed per cow	Year			
	1952	1961	1970	1980
Silage (lb)	5,346	10,000	16,700	17,600
Hay (lb)	3,313	3,100	1,600	1,400
Grain (lb)	2,563	3,400	4,600	5,300
Pasture (days)	184	--	149	125

Table 3--Herds enrolled in DHIA (1981).

Breed	Herds	Cows
Ayrshire	10	556
Guernsey	24	1701
Holstein	856	80,037
Jersey	9	727
Swiss	4	140

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OVERVIEW OF FORAGES IN VIRGINIA

Harlan E. White

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Since Virginia is a transition area between north and south, both cool and warm season forage plants can be grown successfully in the state. There is also quite a transition from west to east as one travels from the mountainous Blue Ridge area in the west through the Piedmont and into the Coastal Plain.

For purposes of forage management recommendations, the state is generally divided into three primary production areas. The northern Piedmont and west of the Blue Ridge area is extremely well suited for the production of Kentucky bluegrass, orchardgrass, tall fescue, the white clovers, red clover, and alfalfa. Timothy will also do well. The middle and southern Piedmont area is not well suited for Kentucky bluegrass and is marginal for orchardgrass, so tall fescue is the primary cool-season species. It is also more difficult to maintain productive stands of legumes in this area due primarily to higher summer temperatures and greater soil acidity. Bermudagrass does reasonably well in the southern portion. The third area of production is the Coastal Plain. Tall fescue is the only reliable cool-season perennial for this area. Bermudagrass does quite well on the sandy soils, but the improved forage types are not widely utilized, primarily because this is a cash crop area with very few livestock operations.

The data in Table 1 indicate average forage yields during 1979 which was an excellent growing season and during 1980 which was a season when severe drought occurred.

Table 1.--Forages in Virginia

	1979		1980	
Crop	Acreage	Yield	Acreage	Yield
Corn Silage	180,000	15.0 T	220,000	11.5 T
Sorghum Silage	8,000	11.0 T	8,000	10.0 T
Alfalfa	90,000	3.0 T	87,000	2.5 T
Hay-All	975,000	1.8 T	967,000	1.7 T
Pasture			2,900,000	

Reliable data for the acreage of the various types of pasture are not available. The data in Table 2 are my estimates of the composition of the 2.9 million acres of pasture in Virginia.

Table 2.--Estimated pasture acreage in Virginia

Type	1978 Acreage
Native, unimproved	1,200,000
Bluegrass, improved	600,000
Orchardgrass-clover	300,000
Tall fescue	800,000

The Virginia Forage and Grassland Council, since its formation five years ago, has become a vital part of the forage educational program in Virginia. For operational and programming purposes, the state is divided arbitrarily into four geological areas. These are the Northern, Valley-Blue Ridge, Southwest, and Southern Piedmont areas. Each of these areas is represented on the Board of Directors which is composed of six forage producers and six forage agri-business representative. There are also six technical advisors representing various agencies associated with forages in the state.

In each of the four areas, an annual forage conference is held each winter. After these are completed, the statewide forage conference and membership meeting is held. The VFGC outstanding forage producer awards are also based on these areas. A selection committee in each area determines the award winner from among nominations submitted. The award winner in each area then receives the award at the area meeting and participates in the program by describing his forage operation. Each summer a forage tour is scheduled in each of the four areas.

The VFGC newsletter, "The Virginia Forager", is prepared on a quarterly basis and sent to all members plus other interested groups in the state. Other activities include the support of important legislation affecting forage producers and promoting needed forage research.

Corn silage is an extremely important source of high-energy feed in Virginia, particularly for the dairy industry. There are approximately 700,000 acres of corn grown each year, of which about 200,000 acres are harvested for silage. There are also about 200,000 acres of corn produced using no-till methods. About one-half of the no-till corn is harvested for silage. The use of no-till techniques has enabled producers to grow corn on fields capable of producing high corn yields but which are often too steep to safely plow. As long as producers ensure that such steep fields are protected by adequate mulch, no-till works very well. However, a growing problem is the attempted production of no-till corn on soils which are not well suited for corn production. The result is relatively low yields and increased erosion in certain areas. Most producers attempt to harvest corn silage in the hard-dough stage of maturity with a resulting dry matter content of 35-40%.

Small-grain silages also play an important role in providing high-energy feed for dairy herds. When the supply of stored-corn silage is depleted in late spring, small grain provides excellent quality silage until the new corn silage crop is available. Barley and wheat are the primary small-grain silages. These are usually harvested direct in the soft-dough stage. A great deal of rye is also used for silage. This is cut in the boot stage, wilted, and then ensiled. Yield of this type of rye silage is lower than from barley and wheat but it offers the advantage of a higher protein feed plus the land is available earlier for corn planting.

In hay making, the large round bales have become commonplace. There is still much to learn about how they should be most effectively stored and fed, but the tremendous savings in labor which they provide is the overriding factor in their widespread acceptance.

Alfalfa is the mainstay for high-quality hay production. Interest in it is increasing dramatically as indicated by increased seed sales and acreage planted. Reasons for this include the need for high-protein feed, the increased costs for planting annual crops such as corn, the potentially high forage yields without the need for expensive nitrogen fertilization, and the ability of alfalfa to protect the soil from erosion once established. Variety recommendations are still made each year, with ten varieties of alfalfa currently being suggested for use by producers.

The alfalfa weevil is still a concern but is not the serious threat that it was in the early sixties. It is now a management factor which must be contended with but producers feel confident in their ability to control the weevil with current insecticides. Many areas do not need to be sprayed for the weevil while other areas need to be sprayed each year. Of

even greater concern than the alfalfa weevil is the potato leafhopper. It has the ability to build up very quickly to population levels which leave the plants yellow and stunted. Producers have not yet learned how to determine when spraying is necessary.

A number of diseases are present in alfalfa in Virginia. Varietal resistance has been a great help in reducing losses from most diseases but there are still problems with anthracnose, the crown and root rots, leaf diseases, and bacterial wilt.

The goal is to harvest four cuttings of alfalfa each season. Each year more of our alfalfa is stored as silage. This helps to reduce losses due to weather and also fits well with the automated feeding systems on most dairy farms.

A serious concern with alfalfa has always been the tremendous soil erosion which often occurs during seedbed preparation and establishment. Much alfalfa is grown on the upland soils which are particularly susceptible to erosion. During the last several years, research results have shown that alfalfa can be established successfully without the need for plowing and establishing a fine seedbed. In the educational program this past winter, emphasis was placed on the techniques necessary for establishing alfalfa by no-till methods. The interest among producers has been tremendous as indicated by their attendance at meetings and demonstrations as well as the number of new no-till drills which have been purchased this spring. Basically, the suggested procedure for no-till alfalfa is two applications of paraquat about two weeks apart and then seeding 15 lbs. of alfalfa per acre with 10 lbs. of 10G granular Furadan in the furrow with the seed. This basic procedure will vary with the type of cover being seeded into, time of year and other such variables.

There is tremendous potential for pasture improvement in Virginia. It is considered a vast under-utilized resource. In the mountainous western portion of the state, limited access to areas which need to be fertilized, mowed, sprayed, overseeded, and even fenced are major obstacles to improving production. Multi-flora rose is a weed pest that is increasing throughout the state. Eastern cedar is another woody species which quickly claims marginal unmaintained pastures. Each year thousands of acres of pasture land are lost to brushy species which are the climax vegetation.

However, Virginia does have many, many excellent pastures which are being well managed and are included as part of well-planned forage systems. Tall fescue is becoming more widespread each year and, despite its palatability problems, producers are learning to manage it to their advantage. They are learning that one of the keys to success with tall fescue

is in keeping it grazed down relatively close and maintaining red and ladino clover in the stand with it. Tall fescue that has been fertilized with nitrogen in mid-August and allowed to accumulate during the fall months also has come to play an extremely important role in providing winter grazing for beef cow herds, beef calves to be over-wintered, dairy heifers, and dairy dry cows.

Overseeding of pastures and hay fields with a mixture of red and ladino clovers is a management practice which has been emphasized heavily in the last several years. That is one of the most economical, simple, and practical management techniques for improving the yield and quality of Virginia pastures and hayfields. The basic recommendation is to seed in late February or early March on a sod which has been closely grazed and is well limed and fertilized. Simply broadcasting the seed (3 lbs. red clover and 1 1/2 lbs. ladino clover per acre) and allowing the cattle to tread the seed into the soil usually results in an adequate stand of clover established in the grass sod. Pulling a chain harrow behind the tractor seeder also helps with soil-seed contact and spreads manure. Freezing and thawing of the soil during that time of the year also helps in stand establishment.

An important aspect of pasture management is proper fencing. Most of the good pasture management practices are dependent on the producer being able to use his judgement in moving livestock as needed in the grazing system. Much of the fencing in Virginia is old and in need of repair. Many fences have been removed, leaving large boundaries which are difficult or impossible to manage. New high-tensile-steel fencing systems show promise in reducing costs and are effective. The need for more and improved fencing as a necessary pre-requisite to pasture management is being emphasized.

In summary, Virginia has tremendous capacity for producing large yields of high-quality forages. The challenge is to develop forage systems which will make use of this potential while providing a profit to the producer.

OVERVIEW OF FORAGE AND LIVESTOCK IN VIRGINIA: BEEF CATTLE AND SHEEP

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I am pleased to have a part on the program of the 38th Southern Pasture and Forage Crop Improvement Conference. My task this morning will be to provide you with a brief overview of the beef cattle and sheep industries of Virginia. These are important livestock enterprises in our state, and they contribute substantial amounts of income to the farm operations of which they are a part. Undergirding the production of beef cattle and sheep are strong forage programs. In Virginia, we have the capability of producing quality forage which allows us to do an outstanding job of beef cattle and sheep production. Your work in forage research and extension is of great importance to Virginia livestock producers who are ever seeking to do a better job of forage production for their livestock.

If time permits, I will also provide a few facts and statistics about the horse industry in Virginia because horses are also forage-consuming animals and play an important role in forage-livestock situation.

Beef cattle numbers have increased by 30% in Virginia over the past 10 years and these increases exceed projections of our beef industry task force made in 1969. A major portion of this increase has been in beef cow numbers which also increased 30% during the decade. This represents one of the higher percentage increases of any major cattle-producing state in the nation. Virginia ranks 26th in total cattle population and is 23rd in the number of beef cows among the states in the union. Beef cows are distributed throughout Virginia but are concentrated in northern Virginia, the Shenandoah Valley, the northern Piedmont and in southwest Virginia. They are found throughout the state in appreciable numbers and we have a number of cow herds in the eastern and southeastern portions of the state, an area which is normally considered a cash crop producing area. Many of these cow herds are located on farms because they can

utilize crop residues or acreages that are unsuited to row crop production. The greatest concentration of cows is in the upper region of the Shenandoah Valley with Augusta County alone having some 91,000 cows. Its neighboring county to the north, Rockingham, is the next highest county in beef cow population with 88,000 beef cows. In northern Virginia, Loudoun and Fauquier counties located close to urban Washington, D. C. are still major beef cow producing areas, each county having close to 50,000 cows. As we move down into the Piedmont region of Virginia, Bedford County just north and east of Roanoke is a large beef cow-calf center as is Washington County located near Abingdon in the southwestern portion of the state. A majority of the counties in southwest Virginia, with the exception of the three coal region counties that border on Kentucky, have from 25 to 40,000 cows each. This makes this a leading area of feeder calf and stocker production.

In keeping with the national pattern, cow herds in Virginia are predominately small operations with approximately 65% consisting of operations of 1 to 49 head. About 16% of the cattle operations have from 50 to 99 head and about another 15% consists of operations with 100 to 180 head. Less than 2% of the cattle operations in the state have 500 head or more.

In 1981, Virginia farmers had cash receipts from the sale of cattle and calves amounting to $215,000,000. This was not a good year financially for cattle producers because prices were down and most purchased items were up in price creating one of the worst financial squeezes for cattle producers that we have seen since the early seventies.

Beef cattle are raised on some 31,000 farms in Virginia and our total number of cattle and calves based on January 1, 1982 census figures was 1,850,000 head, up 6% from the previous year. Dairy cattle make up a portion of this total so that our total number of beef cattle was estimated to be 1,546,000 head on January 1. Of this number, 670,000 were beef cows. This number was up 5% from the previous year. Based on USDA Crop Reporting Estimates, we have about an 86% calf crop each year and the most recent estimate of average weaning weight was 467 pounds.

The general trend of increasing numbers is due to the fact that beef cattle utilize the forage and pasture produced in Virginia primarily on acreages unsuited to row crops because of slope or other factors. Virginia is primarily a feeder-cattle-producing state and has experienced an expansion in beef cow numbers as dairy cow numbers have generally declined over a long period of time. Beef cows currently compose 36% of all cattle and 45% of the beef cattle in Virginia. The growth in cow numbers can be attributed to the fact that cows have a low labor and financing requirement and can utilize pasture, crop residues and by-product feeds more effectively than other classes of

livestock. Cow-calf operators in Virginia are retaining a higher proportion of their calves beyond weaning. This enables them to market more total pounds of beef and to increase the volume and total dollars produced from their cattle operations. Evidence of this tendency toward production of heavier feeders is shown by the fact that we now sell 86% more yearling feeder cattle in fall, summer and spring feeder sales than was the case 10 years ago.

The beef cattle industry in Virginia will continue to grow in size and complexity. A large part of beef cattle owners will continue to be part-time farmers. Beef cattle now constitute the largest proportion of total cattle numbers in the history of the state. For example, in 1950, 40% of the cattle in Virginia were beef cattle, while the present figure is 80%. The Virginia cattle inventory is expected to continue to increase and will reach a peak sometime in the mid to late 80's which will be consistent with the 10-year beef-production cycle and at that time it is expected that numbers will be higher than at any previous time since records have been kept.

Beef cattle producers are a varied group in Virginia and their needs vary greatly as they seek to improve profitability of their operations. Full-time commercial operations are becoming somewhat larger but we have many part-time producers whose operations remain relatively small. A high proportion of our operations consist of cow herds numbering 25 or less. As a result, beef cattle may not be the main enterprise on the majority of farms on which they are produced but they are an important commodity because they utilize pasture and other forages that other classes of livestock are not as well equipped to utilize. Beef cattle are particularly attractive to the part-time farmer or land owner because, in the case of beef cows in particular, they can be produced with a relatively low labor and management input. Practically all beef cattle production systems in Virginia are forage based. Producers generally recognize the advantages of high-quality forages such as corn silage for finishing cattle and for wintering calves for feedlot replacements. However, there is a trend away from the use of corn silage for wintering rations and a shift toward greater use of hay and non-harvested winter forage such as stockpiled tall fescue. Increased emphasis is being placed on the utilization of crop residues by beef cows and there is some interest in using crop residues at least to some extent for young growing cattle. Greater use of stockpiled fescue and crop residues reduces the need for harvested feed for the brood cow herd. This utilization of forage resources may permit expansion of beef cow numbers while at the same time allowing producers to reduce their costs of production.

We have a large poultry industry in Virginia and the broiler litter and other poultry wastes are receiving increased utilization by beef cattle producers. Broiler litter can be

used to supplement and extend the use of low-quality forages for the brood cow herd, can be used in growing rations for young beef cattle and is also used in limited extent as a source of protein in rations being fed to growing-finishing cattle. Research conducted here at Virginia Tech by Dr. Fontenot and others has provided the beef cattle industry with a valuable feed resource which is increasing in use as the broiler industry in our state continues to grow.

Creep grazing is another technique of improved forage utilization which offers the cow-calf producer an opportunity to improve weaning weights and make better utilization of quality forages. This practice has special importance in those areas of the state where tall fescue is the predominant pasture grass and where the preweaning growth of calves can be improved by providing forage of higher quality and palatability during the summer grazing season.

Cattle breeding and improvement programs receive high priority in Virginia. We have a strong performance testing program and this is providing improved breeding stock of greater genetic merit to our producers. Crossbreeding is becoming an increasingly evident fact of life in our cow-calf herds. Over 50% of all the feeder calves sold in our organized sales in 1981 were crossbred. Many of the larger breeds such as Charolais and Simmental are being used in crossbreeding programs which increases the need for improved forage quality and yield consistent with the greater weight-producing potential of these larger cattle and the need to provide optimum feeding programs in order to benefit from their greater genetic potential for growth.

Virginia is a leader in organized cattle-marketing programs and these make a major contribution to the industry in Virginia. Our special sales now market about 20% of all the feeder cattle produced in the state. New and more efficient marketing systems utilizing the tele-auction and electronic marketing techniques for feeder and slaughter cattle offer great promise for future cattle-marketing efficiency. Virginia cattlemen finish only a relatively small proportion of the feeder cattle produced within our state. About 70,000 finished cattle are produced annually meaning that a majority of our calves and stockers are shipped out of the state to be finished elsewhere, primarily in the eastern corn belt and in Maryland and Pennsylvania. There is good potential for increased production of slaughter cattle in Virginia and this is particularly true if high-quality forages can be used to reduce the production cost while maintaining acceptable cattle performance. Up until the present, Virginia slaughter cattle producers have often found it difficult to compete with other market opportunities for corn for cattle finishing. Research programs underway now indicate that it may be possible to produce acceptable slaughter cattle suitable to modern beef

consumer trends using lesser amounts of concentrates than have generally been required in the past. This development could expand slaughter cattle production in Virginia particularly if cattle slaughtering facilities become established within the region or if new marketing techniques such as electronic marketing enable Virginia producers to receive market value for the slaughter cattle they produce.

Sheep are an important livestock enterprise in Virginia and we had on hand as of January 1, 1982 some 170,000 head. These are concentrated in the Shenandoah Valley particularly in Rockingham, Augusta, and Highland counties and to some extent in southwest Virginia. Virginia is the largest sheep-producing state on the east coast and leads the nation in the number of lambs produced per ewe. During 1981, the better managed Virginia sheep flock had an average gross return per ewe of $90 or the equivalent of $450 per animal unit. Well-managed sheep operations continue to show an excellent return per hour of labor and per dollar invested. There is increased interest in sheep production in Virginia and some signs that sheep numbers are on the way up. In the Eastern Lamb Producers Cooperative and a comparable wool-marketing group, marketing programs are established which enable Virginia producers to get top prices for lambs and wool. Much of the lamb produced in Virginia moves into the northeast where the greatest concentration of population regularly consuming lamb is located. At the present time, two projects are under study which could provide lamb-slaughtering capability within Virginia or in a neighboring state. If either of these becomes a reality, the lamb-marketing picture for Virginia sheep producers may become even brighter.

Sheep are the sole livestock species which can produce a top-quality market product with little or no concentrate feeding. This means that the forage program for sheep producers is of utmost importance and one which continues to receive research and extension attention at Virginia Tech. Maintenance of legumes in cool-season-grass pastures, the use of stockpiled fescue to reduce wintering cost for the ewe flock and improved grazing programs for lambs are areas that require greater emphasis. Sheep are produced on some 3,500 farms in Virginia and have a farm value of product in excess of 10 million dollars. The sheep industry will continue to be an important livestock industry within our state.

The horse industry is also a major agricultural industry in Virginia which is based on a strong forage program. It is estimated that there are some 36,000 horse owners in Virginia, 86,000 horses, some 6,600 employees working full time in the horseindustry and about 1,200 horse breeding farms. Of course, many horse owners keep their animals for recreational purposes owning one or two horses. In times of economic adversity, these producers are concerned with ways to keep costs under

control. There is increased demand for quality pasture and hay production programs for use by horse owners and it is this area of emphasis that will be of interest to those of you attending this conference. Virginia is truly horse country and a strong forage program geared to the needs of the horse owner, be it the breeding farm operator or the backyard pleasure horse owner, will serve to support the industry.

It has been my pleasure to share a few moments with you and to relate to you some of the characteristics of the livestock industry of Virginia. It can only be strengthened by strong forage research and extension programs and I look forward to attending as many of your sessions as possible to gain information that will be useful in my work with beef cattle producers. Thank you for the opportunity to appear on your program.

FORAGE MANAGEMENT RESEARCH IN VIRGINIA

D. D. Wolf

Virginia Polytechnic and State University

A broad-based forage program is in progress at Virginia Tech with several SMY appointments in research and extension working cooperatively within several departments. Projects are in progress at Blacksburg, Northern Virginia Forage Research Station, Shenandoah Research Station at Steeles Tavern, Glade Springs Research Station, Piedmont Research Station at Orange, and on cooperating farms in conjunction with local Extension leaders.

NO-TILL ALFALFA

Extensive testing is underway to develop practical procedures and the degree of success in a wide range of previous cropping situations. An Extension publication has been prepared to help farmers with this new practice. Tremendous interest and activity have been shown during this year. Factors contributing to the interest and successes include approved labeling of an insecticide, approved labeling of a herbicide, improved planting machinery, and need for erosion control and economics. Numerous farmers, commercial enterprises, and non-profit organizations (for loan to farmers) have purchased new planting equipment. Careful procedures including proper fertility, adequate vegetation control, and good seed placement have given excellent probabilities of success.

INSECT PROBLEMS WITH ALFALFA ESTABLISHMENT

Extensive stand loss was observed with conventionally established alfalfa not treated with an insecticide. Detailed survey of soil samples and damaged plants showed seed corn maggot feeding caused severe root pruning. Several plantings had greater than 90% seedling loss. Two plantings, however, showed no stand loss. Initial evidence seems to indicate that fields with a winter cover of rye or grass were subject to the

maggot attack when planted to alfalfa in the spring. More study of life cycles and occurrence in other locations and years will be needed to fully evaluate the potential problems of this insect.

BORON FOR PASTURES

Several rates of annually applied boron to clover-grass mixtures have not shown any advantage when grown on Virginia soils. This is the third year of the study.

FALL ALFALFA MANAGEMENT

Ideal timing of harvest schedules are sometimes interrupted and cause the last seasonal growth to accumulate during late summer or early fall. Farmers are often reluctant to harvest during this so-called "critical" period. Such management recommendations have been handed to us by research from Northern locations where such caution is necessary. Our studies, with the concurrence from similar research in other states, indicate that fall harvest management (prior to killing frost) is unique for a climatic transition zone such as in Virginia. The time span between the last two harvests of the season may be the decisive factor. In the Blacksburg area the final harvest can be made before about September 20 or after killing frost without worry. If 50 or more days of growth have accumulated between September 20 and killing frost then a harvest can be made at any fall date. However, if 50 days of growth have not accumulated, then cutting should be deferred until frost or until sufficient time (50 days) has elapsed since the previous harvest.

SERICEA LESPEDEZA MANAGEMENT AND PHYSIOLOGY

Ten improved varieties were planted in 1982 for performance evaluation. Studies are being conducted on minesoils to find ways to convert dominant sericea lespedeza stands to desirable forage for livestock enterprises. Establishment studies on minesoils have shown the most important factor to be a straw mulch with lime and phosphate fertilizer being essential also.

Growth analysis studies and establishment of nonstructural carbohydrates in the fleshy perennial roots have given a basis for selecting management practices that maintain good stands or reduce vigor prior to reseeding with other species.

EQUIPMENT AND FACILITIES

Greenhouse space and six growth chambers are available for special research problems. Instrumentation is available for monitoring most environmental parameters associated with crop growth. Growth analysis, LAI, water relations (plant and soil) and photosynthesis measurements are possible. A new infrared gas analyzer allows simultaneous measurement of carbon dioxide

and water vapor using the same air sample so that both photosynthesis and transpiration can be monitored continuously. All electronic equipment can be placed in a mobile unit and supported by a portable power unit. Controlled environmental chambers are available for single leaf (broad or narrow types) and canopy photosynthesis measurements. A system of powerful lights (four 1000-watt,metal arc lamps) are contained in a reflector so that constant radiation is always available regardless of cloud cover and time of day or year.

Laboratory support for chemical analysis includes automated colorimetric measurements including protein nitrogen and nonstructural carbohydrates. A computerized peak detector records measurements at 40 samples per hour and matches concentrations with sample weights previously entered by an electronic balance so that calculations can be made.

FORAGE FERTILIZATION RESEARCH IN VIRGINIA

R. B. Reneau, Jr.

Virginia Polytechnic Institute and State University

Research is being conducted to determine the response of orchardgrass (Dactylis glomerata L.) and alfalfa (Medicago sativa L.) to S application and the response of alfalfa to plowsole placement of lime and fertilizer amendments. Both of these forages are important in Virginia agriculture. Approximately 36,400 ha are planted to alfalfa and it is projected that this area may increase to 60,700 ha by 1985. Orchardgrass occupies approximately 121,400 ha in Virginia. This includes orchardgrass-legume stands. Alfalfa is receiving increased attention since it has the potential for providing a perennial source of high-yielding and high-quality forage in Virginia. Alfalfa should become more important as the price of N continues to increase.

The response of forage grasses to S application has received limited attention in the Southeastern United States during the past decade. This is unusual considering that Bledsoe and Blaser (1947) reported yield increases with S application in Florida in the 1940's and assessment of the S status in the Southeastern United States has indicated extensive S-deficient areas (Beaton et al., 1971). Sulfur may be less available to crops today because of the use of high-analysis, relatively S-free fertilizers and other soil amendments, the large concentrations of S removed from soils with increased crop yields, and the concern with atmospheric pollutants. With regard to this last factor, data (Table 1) collected by Lutz (unpublished) show the quantities of S added to agricultural land annually via precipitation changed very little between 1957 and 1977. In spite of the potential for increased S deficiency, much of the forage fertilization research with S was conducted prior to 1965 in the Southeastern United States (Jordan and Bardsley, 1958; Neller and Bartlett, 1959; Woodhouse, 1969). In a review of literature, Beaton et al. (1971) indicated that no response to S had been reported for any crop in Virginia prior to 1971. This supported research by Lutz (1957). Sulfur deficiency for

Table 1.--Sulfur added to soil from precipitation at selected locations in Virginia

Location	Time Period 3-1-53 to 3-1-56	3-1-73 to 3-1-77	Change
	------------- kg/ha	--------------	--------------
Blacksburg	23.5	25.3	1.8
Blackstone	----	21.0	---
Buckingham	15.8	19.9	4.1
Charlotte Courthouse	14.6	22.0	7.4
Emory	----	19.6	---
Holland	----	27.8	---
Orange	22.2	24.3	1.9
Warsaw	20.6	23.9	3.3

orchardgrass was observed after 1971 by Lutz (1973) in a field study designed to monitor responses of alfalfa and orchardgrass to P sources. Since that time, Reneau and Hawkins (1980) have shown S deficiencies to occur frequently for certain crops in Virginia.

In the second study, the influence of plowsole amendments on alfalfa yield and longevity is considered. Most of the alfalfa in Virginia is produced in the Piedmont and Appalachian regions where soils often have subsurface horizons that limit the development of the root system because of low pH and low fertility. The subsurface placement of lime and/or fertilizer amendments has potential for improving the soil environment and this may have positive benefits on alfalfa yields and stand longevity. The subsurface application of lime reduces the problem of Al toxicity and should increase the soil volume available for moisture and nutrient extraction or both. Even though the potential for alfalfa response to plowsole placement of lime or deep mixing of lime and fertilizer is large, limited data are available on this subject. There are, however, results available from similar experiments (Camper and Lutz, 1977; Doss et al., 1979; Long et al., 1972; Lutz and Jones, 1975; and Lutz et al., 1975).

The potential for altering the pH or P concentration in these subsurface horizons as a function of surface application is limited, particularly in fine-textured materials. Metzger (1934) and Brown and Munsell (1938) noted that it took approximately 10 to 14 years to increase the soil pH at a 15-cm depth with surface lime application. Lutz et al. (1956) reported that where various sources of P were applied initially at rates

of 168 to 1,008 kg/ha and with annual applications of 168 kg P/ha, after eight years P penetration was limited to the 10-15-cm depth. This implies that subsurface placement of lime and P may be the only feasible way of influencing the pH and fertility of subsurface horizons in such a manner as to be beneficial to perennial legumes over extended periods.

MATERIALS AND METHODS

Sulfur Studies

'Virginia Common' orchardgrass was seeded in a Groseclose silt loam (Typic Hapludult; clayey, mixed, mesic) soil at the Virginia Polytechnic Institute and State University, Main Experiment Station at Blacksburg, Virginia in 1974. This soil has extractable soil SO_4-S concentrations of 11, 40, and 60 µg/ml [extracted with $CaPO_4$ in 2 N acetic acid (Hoeft, et al., 1973) and determined turbidimetrically (Tabatabai, 1974)] in the Ap, 25-50, and 50-75 cm depths. Fertilizer applications consisted of 56 kg N, 20 kg P, and 75 kg K/ha applied each spring and an additional 56 kg N/ha as NH_4NO_3 applied after each harvest. Alfalfa 'Arc' was established on the same soil in 1979 and was fertilized at recommended rates. Both of these experiments received spring applications of S at rates of 0, 17, 34, and 51 kg S/ha from $CaSO_4$.

Latin square designs were utilized (4 x 4) with each plot having dimensions of 2.4 x 4.6 m. Forage was collected from each plot at recommended growth stages for yield and S and N concentrations in the forage.

Nitrogen and S concentrations in the forage were determined after oven drying at 80 °C for 24 hours and grinding in a Wiley mill with stainless steel points to pass a 40-mesh screen. Total N was determined colorimetrically after digestion in a block digestor. Total S in the forage was determined turbidimetrically after the tissue was wet-ashed in a nitric-perchloric acid solution (Tabatabai and Bremner, 1970).

Plowsole Placement of Lime and Fertilizer Amendments

In 1969, the plowsole amendments listed in Table 6 were made to a Davidson clay loam soil in Orange, Virginia. These amendments were placed in the plowsole in a thin sheet by hand. From 1969 to 1977 soybeans were produced on these plots. In 1977 the experimental area was seeded to 'Arc' alfalfa at the recommended rate. The experimental design was a completely randomized block design with respect to plowsole amendments and split with irrigation levels consisting of no irrigation and irrigation as indicated by gravimetric soil moisture determinations.

RESULTS AND DISCUSSION

Response of Forages to Sulfur Application

Research on the response of forages to S application in Virginia is limited and is restricted to orchardgrass, alfalfa, and corn (*Zea mays* L.) silage.

In a survey of N, S, and N:S ratios of 127 corn silage samples in Virginia (J. A. Lutz, Jr., unpublished data), a wide range in N:S ratio and S content was noted (Table 2). If we

Table 2.--The distribution of N:S ratios for corn silage samples in Virginia

N:S ratio	Samples No.	Samples %	Average N	Average S
			- - - % - - -	
10	4	3	1.24	.14
10-16	39	31	1.24	1.09
16-20	12	9	1.07	.06
21-30	28	22	1.38	.05
31-50	21	17	1.18	.03
51-100	19	15	1.29	.02
100	4	3	1.16	.01

Source: J. A. Lutz, Jr. (unpublished data)

assume that an N:S ratio of 16 is adequate, then approximately 34% of the samples fall into this category. Since N:S ratios above 20 indicate a severe S deficiency, which may limit protein formation (Stewart and Porter, 1969), then 57% of the samples analyzed come under this category. The increased N:S ratio reflects the decreasing S concentration in these samples (Table 2) since N concentration did not consistently increase or decrease. These data indicate that a large percentage of corn silage used in Virginia may be deficient in S.

Alfalfa and orchardgrass yields as a function of S application have also been monitored. Alfalfa yields (Table 3) were not significantly increased with S application, but there was a trend toward increased yields with increased S application. For alfalfa, the critical concentration has been shown to range between 0.20-0.30% (Spencer, 1975) with the value of 0.25% generally considered as critical. The S concentration in the tissue and the trend of increased yields with increased S application seems to indicate that S sufficiency is marginal with respect to alfalfa. This implies that decreased S inputs in the future may result in S deficiency for alfalfa in this

Table 3.--Alfalfa yields as influenced by sulfur application to a Groseclose silt loam soil

Sulfur Treatment Source	Rate	Alfalfa Yield	% S[1]
		- - - kg/ha - - -	
None	0	14,700a[2]	0.25b
$CaSO_4$	17	15,000a	0.27ab
$CaSO_4$	34	15,100a	0.28ab
$CaSO_4$	51	15,200a	0.31a

[1]Concentration present in the tissue at the last harvest.

[2]Means in the same column not followed by the same letter are significantly different at the .10 level.

soil. The large concentration of extractable soil S in this fine-textured Groseclose silt loam soil and the potential for extensive root development by alfalfa might indicate that S from subsurface horizons is being utilized. These data indicate that shallow-rooted legumes or legumes grown on coarser textured soils in Southwestern Virginia for forages may respond to S fertilization. For orchardgrass (Table 4) sig-

Table 4.--Response of orchardgrass on a Groseclose silt loam soil

Sulfur Treatment Source	Rate	Orchardgrass Yield 1979	1980	1981
None	0	10,700b[1]	8,700a	9,950b
$CaSO_4$	17	11,600a	8,800a	10,450a
$CaSO_4$	34	11,100ab	8,950a	10,550a
$CaSO_4$	51	11,450a	8,800a	10,300ab

[1]Means in the same column not followed by the same letter are significantly different at the 0.10 level.

nificant increases in yield were obtained in two of the three years of the study. The failure of orchardgrass to respond to S application in 1980 is probably related to the availability of atmospheric sources of S and the relative low yield. The

critical concentration for grasses is reported to be between 0.14-0.30% (Spencer, 1975) with the critical concentration for orchardgrass normally considered to be about 0.20%. The S concentration (Table 5) for orchardgrass samples from the

Table 5.--Sulfur and N concentration of the last orchardgrass harvest as influenced by S application to a Groseclose silt loam for 1979, 1980 and 1981

Sulfur Treatment Source	Rate	N	S	N/S
	kg/ha	- - - - - - -	% - - - - - - -	
		1978		
None	0	2.76a	0.19b	14.5a
$CaSO_4$	17	2.55a	0.33a	7.8b
$CaSO_4$	34	2.67a	0.33a	8.2b
$CaSO_4$	51	2.51a	0.38a	6.7b
		1980		
None	0	2.71a	0.28a	10.0a
$CaSO_4$	17	2.66a	0.30a	9.1a
$CaSO_4$	34	2.65a	0.33a	8.2a
$CaSO_4$	51	2.60a	0.32a	8.3a
		1981		
None	0	-	0.17b	-
$CaSO_4$	17	-	0.27a	-
$CaSO_4$	34	-	0.26a	-
$CaSO_4$	51	-	0.28a	-

[1]Means in the same column not followed by the same letter are significantly different at the 0.05 level.

final harvest for both 1979 and 1981, where significant increases in yields were measured, was below 0.20%. In 1980 when no response was observed, the S concentration in tissue from the 0 kg S/ha application rate was above the 0.20% level (0.28%). These data indicate that S responses might be expected in many areas of southwest Virginia and surrounding states. More research needs to be conducted to determine the extent of S deficiency.

Plowsole Placement of Lime and Fertilizer Amendments for Alfalfa Production

Alfalfa yields for plowsole amendments at different irrigation levels were not significantly different at the 5% level (Table 6). For 1978 where lime was not applied in the plowsole, yields were significantly decreased with irrigation compared to nonirrigated conditions (10% level). Where lime was

Table 6.--Alfalfa yields for 1978 and 1981 as influenced by plowsole amendments made to a Davidson clay loam soil in April, 1969

Treatment No.	Plowsole Amendments (30 cm) P	K	Lime	Alfalfa Yields 1978 Irrigation Yes	No	1981 Irrigation Yes	No
	kg/ha			Mg/ha			
1	488	93	22,400	11.4	10.8	12.8	10.5
2	488	465	22,400	11.5	8.1	12.5	9.6
3	49	930	22,400	10.0	8.9	11.3	10.2
4	244	930	22,400	11.0	8.1	10.4	9.3
5	244	930	22,400 + A	10.9	10.1	12.9	11.9
6	244	930	0	9.3	8.8	3.7	7.1
7	0[1]	0	0	7.7	6.9	2.9	6.5
8	0[2]	0	0	8.0	6.3	2.3	7.2
9	186	930	22,400	11.6	9.6	10.0	11.0

LDS 5%: Irrigation means, NS; between treatments at the same irrigation level, 2.6 (1978) and 2.4 (1981); between treatments at different irrigation levels, NS.

[1] 336 kg M.El./ha applied to the surface in 1969.

[2] 1120 kg/ha of 20% acidulated rock phosphate (38% P_2O_5) applied.

A = 670 kg M.El./ha.

applied in the plowsole yields were increased in 1978 and 1981 with irrigation and 1981 without irrigation compared to treatments that did not receive a plowsole amendment. These data indicate that Al toxicity in the subsurface soil horizons may be limiting yields in the Davidson soil. The fact that yields were not significantly reduced without irrigation in 1978 would be consistent with this conclusion. When P was applied in the plowsole in the absence of lime, yields were not significantly reduced in 1978 but were decreased in 1981. This would be expected with Al toxicity since P can act as a liming material by precipitating Al. It is also interesting to note from a longevity aspect that yields under both irrigated and nonirrigated conditions where lime was placed in the plowsole were not reduced after four full years of alfalfa production.

This research indicates that for soils not normally noted for Al toxicity, such as the Davidson, acidity in the subsurface horizon may be limiting yields and stand longevity. Also the problem associated with stand longevity as a result of disease problems in Virginia appears to be lessened with plowsole lime treatments. This is probably a reflection of the general vigor of the alfalfa stand. More research is being conducted in this area to determine the full effect of these plowsole treatments on yield, quality and longevity of alfalfa.

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OVERVIEW OF FORAGE AND LIVESTOCK RESEARCH IN VIRGINIA: PASTURE UTILIZATION BY DAIRY CATTLE

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In dairy cattle nutrition, forage is always central to our research effort. In many instances we have studied specific forages. Much of this effort was with small-grain silages, which will be covered in my later presentation. Over the years, rather than emphasize a particular forage species, we have evaluated the use of fiber for forage description and as a total ration-balancing tool. Especially since Virginia was a heavy corn-silage-utilizing state, using fiber was successful and was the basis for determining forage-concentrate ratios in the lactating-cow ration. This concept continued into the computerized ration-balancing program generally adopted in the Southeast.

Currently we are examining physical form of forages (ground or chopped) and the influence of ensiling hay with corn silage on animal performance and fat test. Ensiling appears to stimulate maintenance of fat test. For the remainder of this presentation, I will aummarize seven years of pasture research.

One dictionary's definition of pasture is "ground covered with grass or herbage, used or suitable for the grazing of cattle etc.; grassland." We have many acres of land in Virginia that fit this definition whether or not they are being used for grazing. Just being available for pasture gives no indication of quantity or quality--nor does it indicate how well growth or milk production will be supported. Pasture studies with lactating cows were not uncommon several years ago, but in more recent times, research effort has generally been directed towards better understanding of cow digestion and nutrition and towards the development of drylot feeding practices. This is reasonable because pasture supplies a rather limited portion of the annual nutrient needs of lactating cows.

Quantity and quality of pasture do vary widely. If palatable species are predominant, quantity at a given moment is recognized, but assessment is more difficult when the palatable

species have been shortened by grazing. Quality is dependent on species, rate of growth, and physiological maturity of the plants. With knowledge of species of their growth, one can learn how to estimate quality. Quality can be determined by chemical forage analysis; the problem is securing a representative sample for analysis. This problem is magnified even more by the fact that cows selectively graze--that is, the quality of forage cows consume will exceed the average of the sward. The feeding value of pasture, when composed of an actively growing mixture of palatable grasses and legumes, cannot be exceeded for lactating cows. On a dry basis, pasture consumed by cows will contain 16% crude protein and will be in the low 20's in acid detergent fiber content. Therefore, pasture is usually much higher in available energy and certainly equivalent in protein to good-quality alfalfa hay or haylage.

Since pasture does contribute to the rations of lactating cows in Virginia and has the potential to contribute even more protein and energy in a number of herds, we decided to conduct pasture research with lactating cows that have a high capacity for milk production. These experiments were conducted over seven grazing seasons.

As a result of these experiments, we have arrived at the following conclusions: Actively growing, good-quality pasture is high in protein, and when supplemented with sixteen pounds daily of ground corn and minerals, milk production is equal to that obtained from conventional, complete, corn-silage-based rations. The nutrient specifications of these two rations are similar in protein and probably in energy; therefore, changing abruptly from one ration to another is not disruptive, especially when the animals are totally familiar with both rations. Sixteen pounds of corn supplement for cows on pasture resulted in more milk than 12 or 8 pounds of corn, but the fat test was usually 0.2% to 0.3% less. A complete corn-silage ration limited to 50 pounds/day for pastured cows supported milk production as well as 16 pounds of supplemented ground corn. Fifty pounds of corn silage daily was not as supportive of milk production as 16 pounds of ground corn, but maintained a 0.2% superior fat test. Hay (3 pounds daily) fed with ground corn did not improve the fat test of grazed cows.

The topic "Optimum Pasture Supplementation" as I have interpreted it is to produce milk near the animal's potential yet to make maximal use of the pasture feed resource. To accomplish this requires extremely good management and a judgment on pasture quality and quantity. Following are a number of considerations that I believe to be extremely important if pasture is to contribute much to our daily feeding programs.

1. During active growth, protein is adequately supplied by pasture, but supplemental energy (12 to 16 lb corn) tend t- maintain more production and extend pasture.

2. Maintaining proper pH and fertilization practices are essential for luxuriant growth. Poor growth is not conducive to milk production.

3. Palatable, good-quality pasture is essential. This can include many species, but they must be actively growing to supply optimal nutritive value.

4. At least 0.5 acre per cow is needed to make an important nutrient contribution throughout the grazing season. However, less area per cow can be effectively utilized for shorter periods, by supplementing heavily with a complete feed.

5. Always graze heavily in the beginning of the growing season. This controls weeds, allows legumes to survive, and result in less overmature, low-quality growth.

6. Don't assume that animals are well fed just because considerable forage has accumulated. If several species are present, the more palatable may be eaten to the ground, while others have gotten more mature and are even less palatable. Note grazing patterns, degree of body fill, and daily milk production to determine pasture adequacy.

7. Rotational grazing, at least to some degree, is desirable. This assures fresh growth and permits followup grazing by dry cows, heifers, or beef cows to clean up the less palatable pasture.

8. Make sure shade and water are available. Preferably, water should be located at least one-half the most distant point from the entrance.

9. Grazing fresh pasture may have management and nutritional advantages that result in longer productive life.

10. Good-quality pasture is ideal for growint heifers, but must be supplemented as growth declines with summer maturity. Even lower quality pasture provides adequate nourishment for mature dry cows.

HIGHLIGHTS OF FORAGE-LIVESTOCK RESEARCH IN VIRGINIA

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INTRODUCTION

The use of forage for livestock production has received increasing attention in recent years as the demand for grain for human consumption has increased and it has become less profitable to feed grain to livestock. Forages have always comprised a large portion of the ruminant diet. However, too often their value has gone unrecognized and comparatively little emphasis has been placed on their economic and nutritive potential. Their use as high-quality animal feed, as a cash crop, and their role in soil conservation and soil fertility is now realized and both extensive and intensive research is needed to optimize their use.

The following forage-livestock research is currently in progress with the objectives of developing management and utilization practices for maximum economy and efficiency of animal production and optimizing forage quality.

UTILIZATION OF FORAGES FOR BEEF CATTLE MARKETING ALTERNATIVES FOR THE SOUTHEAST UNITED STATES

Traditionally, beef cattle raised in Virginia have been shipped elsewhere for feedlot finishing and slaughter. Due to transportation and feeding costs, it may be economically advantageous to finish cattle in Virginia on high-forage rations. If not, Virginia cattlemen have the option of retaining ownership of cattle finished elsewhere. This research in progress at two locations in Virginia (Va Forage Research Station and Southwest Virginia Research Station) and one in Oklahoma (Southwestern Livestock and Forage Research Station, El Reno, OK) compares relative advantages of finishing cattle in Virginia on high-forage rations with shipping them to the Southwest for feedlot finishing. Five systems are used. Two systems utilize light weanling cattle and three utilize heavy weanlings. All cattle are kept in Virginia until mid-February on stockpiled

fescue. One system of heavy and one of light cattle (Systems 2 and 5, respectively) are then transferred to Oklahoma where they graze wheat (*Triticum aestivum* L.) pastures and warm-season perennials followed by feedlot finishing on a high-grain ration. Two systems of heavy and one system of light cattle are retained in Virginia (Systems 1, 3, and 4, respectively), are fed hay for the remainder of the winter and then sequence-grazed on bluegrass-white clover (*Poa pratensis* L. and *Trifolium repens* L.), fescue-red clover (*Festuca arundinacea* Shreb. and *Trifolium pratense* L.) and alfalfa-orchardgrass (*Medicago sativa* and *Dactylis glomerata* L.) pastures in the summer. They are finished on either grain-on-grass at 1% of bodyweight (System 3) or on high-corn-silage rations (Systems 1 and 4). System economics as well as carcass grades and quality are determined.

The project is in the second and final year. Preliminary results for finished weights and carcass grades for the first year are given in Tables 1 and 2.

Table 1.--Performance of steers on different forage-livestock systems in Virginia and Oklahoma

System	Weight by date, lb. 12/9	3/3	4/21	7/7	11/3	2/4	3/22	Carcass grade[a]
1	566	646	693	-	921	1160	-	9.8
2	554	636	763[b]	820	1189[c]	-	-	12.2
3	577	651	751	-	1057	-	-	11.5
4	375	452	493	-	744	-	1063	9.6
5	395	460	586[b]	664	1132[d]	-	-	12.3

[a]Code: 10=avg. good; 13=avg. choice; etc. [b]May 8, 1980.
[c]Oct. 20, 1981. [d]Dec. 8, 1981.

Table 2.--Performance of heifers on different forage-livestock systems in Virginia and Oklahoma

System	Weight by date, lb. 12/9	3/3	4/21	7/7	11/3	2/4	3/22	Carcass grade[a]
1	510	572	618	-	805	1024	-	9.5
2	506	573	681[b]	739	1040[c]	-	-	11.7
3	525	591	654	-	983	-	-	10.5
4	382	435	486	-	684	-	991	11.0
5	405	449	570[b]	623	1046[d]	-	-	12.3

[a]Code: 10=avg. good; 13=avg. choice; etc. [b]May 8, 1980.
[c]Oct. 20, 1981. [d]Dec. 8, 1981

FORAGES FOR BEEF PRODUCTION FROM CONCEPTION TO SLAUGHTER

The effects of various forage species and systems on reproduction and calf weaning weights have been investigated. Tall fescue is a cool-season perennial grass well adapted to Virginia conditions. Its value for stockpiling is well known. However, it has been shown in previous research at Middleburg that cows grazing tall fescue year-round wean lighter calves (Hammes et al., unpublished data). The research of Petritz et al. (1980) showed that cows and calves on fescue systems had lower conception rates, lower weaning weights and lower net returns than animals on tall fescue, legume or orchardgrass pastures. The effects of tall fescue and other initial forage systems on calf performance during later stages of animal production need to be better understood.

Approximately 80% of the beef produced in Virginia is from herds of fewer than 50 animals. Forage and animal systems adapted to small farm situations with minimum inputs of labor, equipment and fertilizers need to be developed. Research begun in April, 1982, at the Virginia Forage Research Station addresses these and other problems. Calf production from conception to slaughter is investigated in three phases.

Cow-Calf Phase

Spring calving cows are maintained year-round on one of six forage systems with two replications of each system. Three systems utilize bluegrass-white clover and three, fescue-red clover. Each bluegrass or fescue system is combined with either orchardgrass-alfalfa, orchardgrass-red clover or fescue-red clover for stockpiling, creep grazing and hay harvesting. Hay is fed to cows during periods of low forage availability. Total forage production by each system is included in the economic analysis.

Growing Phase

All calves are weaned in October and assigned to seven systems for wintering as follows: stockpiled fescue fertilized with nitrogen, stockpiled fescue plus alfalfa, stockpiled fescue plus red clover, ensiled fescue, fescue hay, orchardgrass-alfalfa hay, and a second stockpiled fescue plus nitrogen system. The second fescue plus nitrogen system will provide forage for one set of calves maintained entirely on fescue from conception to slaughter. Two objectives of this phase are to investigate the use of legumes and nitrogen fertilization for stockpiling forages and alternative methods of handling fescue for winter feeding requiring different inputs of equipment and labor.

Finishing Systems

Calves will sequence-graze bluegrass-white clover and fescue-red clover, or bluegrass-white clover and orchardgrass-alfalfa. Calves from the second stockpiled fescue growing system will graze nitrogen-fertilized fescue. Heifers from all systems will be fed grain-on-grass (1% bodyweight) beginning in April and will be slaughtered in July. One-half of the steers from each system will also be fed grain-on-grass beginning in July and will be slaughtered in October. The remaining steers will be finished on a high-corn-silage ration beginning in October and will be slaughtered in January.

This research will provide information on finishing cattle at various times of the year as well as comparative economic advantages of the various production phases. Management and production information will be elucidated that is applicable to small farm situations with varying capabilities in terms of land, labor and equipment.

ENSILING CHARACTERISTICS, PALATABILITY, AND DIGESTIBILITY OF TALL FESCUE SILAGE

Stockpiled tall fescue deteriorates in quality in late winter, resulting in the loss of high-quality grazing and the need for supplemental feeding (Bagley, 1978). Ensiling part of the stockpiled forage would avoid this loss of quality. Also, spring growth is often in excess of forage needed for grazing. Ensiling excess spring growth may be a practical alternative to making hay. Due to spring weather conditions, silage can usually be made at an earlier, higher quality growth stage than hay. Ensiling characteristics of both stockpiled and spring-growth tall fescue are being investigated.

A fescue field at the Virginia Forage Research Station at Middleburg, was fertilized in early August, 1980 with 112 kg/ha of nitrogen and then stockpiled. On November 25, 1980, the forage was cut with a conventional cutter-bar-mower, raked and chopped with a Fox harvester and packed into 55-gallon drums double-lined with polyethylene for ensiling. The forages were ensiled alone, with 0.3% formic acid, 5% ground corn grain or 5% molasses. Additives were mixed with the forages in a horizontal mixer. Dry matter of the forage at ensiling was 31%, crude protein content was 13.6%, and soluble carbohydrate was 18.1%.

The lactic acid content and pH of the ensiled forages is given in Table 3. All silages had excellent ensiling characteristics with desirable appearance and aroma. Little advantage was noted for any of the additives over fescue ensiled alone.

A digestion trial was conducted with 24 wether lambs blocked by breed and weight and assigned to the four silage treatments.

Table 3.--Lactic acid content and pH of ensiled stockpiled tall fescue with three additives

Parameter	None	Formic acid	Ground Corn	Dry molasses
	Additive treatment			
pH	4.4[a]	5.0[b]	4.4[a]	4.4[a]
Lactic acid[c], %	8.0[b]	1.2[a]	7.2[b]	7.2[b]

[a,b]Means with different superscripts in each row are different ($P \leq .05$).

[c]Dry basis.

The trial consisted of a 7-day collection period preceded by an 8-day preliminary period. Silage dry matter digestibility was 63, 64, 65 and 66.7% for the forage ensiled with molasses, formic acid, alone and with corn grain, respectively.

A palatability trial was also conducted with 24 wether lambs. The trial consisted of an 8-day measurement period preceded by a 10-day preliminary period. Dry matter intake was high for all silages. Intake expressed as percent of bodyweight was 3.30, 2.98, 3.51, and 3.59 for fescue ensiled alone or with formic acid, corn or molasses, respectively. Differences were not significant.

Research with spring-cut (May and June) silages is now in progress. Digestion and palatability trials with cattle are being conducted to compare spring-growth silage, stockpiled fescue silage, fescue hay and corn silage. The potential of ensiled fescue for finishing cattle will also be investigated. Spring-cut fescue silage, fed alone or with supplemental grain, will be compared with ensiled stockpiled fescue and corn silage as feedlot finishing rations for steers. This research will be conducted at the Virginia Forage Research Station at Middleburg.

NITROGEN SUPPLEMENTATION TO POOR-QUALITY HAY FED TO STOCKER CATTLE

Weather conditions are often unfavorable for high-quality hay production. Additionally, the need to reduce labor and storage costs has resulted in much hay being stored in large packages outside. These and other factors have resulted in the accumulation and feeding of much poor-quality hay. The potential of supplementation to improve utilization of poor-quality hay is being investigated.

Growing heifers and steers were fed fescue hay ad libitum for 117 days during the winter with one of the following supplements: (1) none, (2) 80% deep-stacked broiler litter, and 20% corn grain, (3) liquid urea-molasses supplement injected into the bales, (4) liquid urea -molasses supplement, self-fed, and (5) soybean meal. The injected supplement did not distribute evenly through the bales and tended to concentrate in the lower back portion. This occurred even though injection was at three sites in the top half of each bale. Average daily gains were low when no supplement was used or when liquid supplement was injected into the bales. At the end of 117 days, all calves were put on pasture for 164 days. By the end of the grazing period, all calves had made compensatory gains and no differences were observed between the groups.

SPRING GRAZING OF ALFALFA

Alfalfa, a perennial legume, is well known for its high yields of high-protein forage. Attempts to graze alfalfa, however, have generally indicated that stand longevity was shortened unless grazing was delayed until the crop was at an advanced growth stage, usually similar to the growth stage recommended for hay harvest. At this stage, yields are high but digestibility, percent protein and energy value have declined.

Early spring grazing could be a tool to delay the first hay harvest until more favorable weather conditions exist for proper drying. It might also be an effective way of reducing alfalfa weevil populations and could certainly provide high-quality grazing during a time when other forages are in short supply.

Research is now in progress to investigate the effects of grazing sheep for 0, 2, 4, or 6 weeks after the alfalfa begins growth in the spring. Two grazing intensities (light and heavy) are used. Preliminary results indicate that light grazing has no advantage over heavy grazing. Plots grazed for 6 weeks have not shown depressed hay yields during the remainder of the season, indicating that spring grazing did not reduce stands during the first year (Table 4).

GRASS TETANY

Grass tetany, a metabolic disorder of ruminants, is characterized as a physiological deficiency of magnesium (Mg). Research has implicated a number of factors which appear to be involved. Extensive research at Virginia Tech has shown that high potassium (K) levels depress Mg utilization (Newton et al. 1972) and that the effect appears to be principally preintestinal (Greene et al., 1982). Spring growth of forage grown with excessive K fertilizer can contain levels of K which have been shown to depress serum Mg levels. Heavy nitrogen (N) fertilization has been implicated by some researchers in grass

Table 4.--Alfalfa hay yields following grazing at two pressures for 0, 2, 4, or 6 weeks during the spring

Grazing pressure	Duration of grazing; weeks	Hay yield, lb. Total	After 6 wks. grazing
Light	0	11,720	6,680
	2	10,030	
	4	10,270	
	6	6,960	6,960
Heavy	0	11,810	7,170
	2	9,090	
	4	9,050	
	6	6,810	6,810

tetany outbreaks. Research at this University, however, has shown that while N fertilization can depress the utilization of Mg in the forage, excessive intake of N *per se* by the animal does not affect Mg utilization (Moore et al., 1972).

Research in Louisiana implicated a possible relationship between aluminum (Al) ingestion by grazing cattle and the occurrence of grass tetany (Allen and Robinson, 1980). Forage samples collected from pastures during tetany outbreaks contained concentrations of Al ranging from 1000 to 8000 ppm. The potential for plant uptake of Al and the role of Al ingestion as either soil contamination or plant-accumulated Al in Mg metabolism is being investigated.

A metabolism experiment was conducted with wether sheep maintained on tall fescue hay to investigate the effect of Al on Mg and calcium (Ca) utilization. Sheep received the following treatments intraruminally during a 10-day treatment period: Control, 1000 ppm Al as chloride or sulphate and 2000 ppm Al as chloride, sulphate or citrate. Serum Mg levels were lowered significantly ($P \leq .05$) by the high Al treatments (Table 5). Valdivia (1977) also reported depressed serum Mg levels in sheep fed 2000 ppm Al as aluminum chloride for 56 days. Absorption of Mg and Ca was not depressed by Al treatments but urinary excretion of Mg was increased by the high Al treatments ($P \leq .05$). Calcium excretion in the urine was increased by all Al treatments ($P \leq .05$). Aluminum absorption occurred with all treatments and is in agreement with the research of Ondreicker et al. (1971) who showed that a 200-mg/kg dosage level of aluminum sulphate greatly increased retention of Al in rats.

Preliminary experiments have been conducted to investigate the potential for Al accumulation by ryegrass (*Lolium multiflorum* L.) from five chelates of Al. Ryegrass was grown in Hoaglands nutrient solution plus the Al treatment for two weeks in a

Table 5.--Serum magnesium levels in sheep dosed via rumen cannulae with Al as sulfate, chloride or citrate

Treatment		
Form	Al level (ppm)	Serum Mg(mg/dl)
Control	0	2.34[a,b,c]
$Al_2(SO_4)_3$	1000	2.28[c]
AlCl	1000	2.36[b]
$Al_2(SO_4)_3$	2000	2.20[d]
AlCl	2000	2.22[d]
Al-citrate	2000	2.04[e]

[a] Means of 10-day treatment period.

[b,c,d] Means with different superscripts are different ($P \leq .05$).

growth chamber. Results indicate that ryegrass can tolerate up to 200 ppm Al when applied as Al-citrate but no significant uptake of Al occurred in the top growth. However, experiments with treatment periods of 3 weeks resulted in top growth concentrations of 1800 ppm Al. The Al treatments depressed concentrations of phosphorus (P) and increased concentrations of K in the top growth. Further research is in progress to elucidate these effects.

THE EFFECT OF SULPHUR AND NITROGEN FERTILIZATION ON YIELD AND QUALITY OF ORCHARDGRASS AND ORCHARDGRASS-RED CLOVER

Sulphur (S) is an essential element for both plants and animals. It is required by plants in approximately the same amounts as P. In the past, it has usually not been necessary to fertilize with S because the soil supply has been adequately replenished due to the content of S in commonly used phosphate fertilizer, the S content of some pesticides and the S contribution from air pollution (Tisdale and Nelson, 1975). While air pollution continues to be a major source in some areas, the use of S-containing chemicals has declined. Increasingly, areas have been found to respond to S fertilization in other states. Virginia has been among the last states to report an S-deficiency problem (Beaton et al. 1971). However, a survey of corn silage samples at Virginia Tech (unpublished data) has indicated a possible need for S fertilization.

Experiments are being conducted at two locations in Virginia (Steeles Tavern and Tazewell) to investigate the effects of S and N on yield, chemical composition and *in vitro* dry matter digestibility (IVDMD) of orchardgrass and orchardgrass-red clover.

Three levels of nitrogen, 0, 224 and 448 kg/ha/yr, were applied in split applications to the pure grass stands at Steeles Tavern. Red clover was seeded at the rate of 9 kg/ha in the

Table 6.--Effects of Nitrogen and Red Clover on the Crude Protein,[a] Fiber Components[a] and IVDMD of Orchardgrass

Component	Nitrogen fertilization, lb/ac/yr 0	200	400	Red clover
	%	%	%	%
Crude protein	12.2[b]	15.9[c]	17.6[d]	12.3[b]
Neutral detergent fiber	65.8[b,d]	67.6[c]	64.6[d]	66.1[b]
Acid detergent fiber	37.2[b]	36.7[b]	35.3[c]	37.2[b]
Lignin	5.5[b]	6.6[c]	6.4[c]	5.3[b]
Cellulose	30.4[b,d]	29.3[b,c]	28.5[c]	31.5[d]
Hemicellulose	28.6[b]	31.0[c]	29.4[b]	28.9[b]
In vitro dry matter digestibility	54.4[b]	56.4[c]	58.2[d]	55.4[b,c]
Nitrogen:Sulphur	7.8[b]	12.6[c]	16.7[d]	8.8[b]

[a]Dry matter basis.

[b,c,d]Means on same line with different superscripts are significantly different at (P<.05).

Table 7.--Effects of Sulphur on the Crude Protein,[a] Fiber Components[a] and IVDMD of Orchardgrass

Component	Sulphur fertilization, lb/ac/yr 0	30
	%	%
Crude protein	14.0[b]	15.0[c]
Neutral detergent fiber	66.6[b]	65.5[c]
Acid detergent fiber	36.4[b]	36.8[b]
Lignin	6.1[b]	5.8[b]
Cellulose	29.7[b]	30.2[b]
Hemicellulose	30.2[b]	28.7[c]
In vitro dry matter digestibility	51.1[b]	57.2[c]
Nitrogen:Sulphur	13.6[b]	9.3[c]

[a]Dry matter basis.

[b,c]Means on same line with different superscript are significantly different at (P<.05).

fall of 1980. Sulphur as calcium sulphate was applied in a split-plot design at the rate of 0 or 32 kg/ha/yr.

The effects of N fertilization (averaged over levels of S fertilization) on chemical composition and IVDMD of orchardgrass are given in Table 6. Crude protein and IVDMD increased with increasing levels of N fertilization. Red clover had no significant effect on the chemical composition of the companion orchardgrass. It was noted, however, that clover constituted only 8% of the stand.

The effects of S (averaged over levels of N fertilization) on chemical components and IVDMD of orchardgrass are shown in Table 7. Added S increased the S content of the forage and significantly increased crude protein and IVDMD.

In vivo trials are being conducted to investigate the effects of N and S fertilization on digestibility of the forages.

THE EFFECT OF MEFLUIDIDE ON THE YIELD AND QUALITY OF ORCHARDGRASS AND GAINS OF YEARLING STEERS

The use of mefluidide to suppress seedhead formation and improve the quality of orchardgrass under grazing conditions is being investigated. Mefluidide, at the rate of 0, 0.22 and 0.28 kg/ha, was applied to orchardgrass in early spring of 1982. Treatments are replicated 3 times and are stocked at the rate of 4 steers per 3.3 acres. Forage samples collected at 28-day intervals will be analyzed for fiber components, soluble carbohydrate, crude protein, mineral analysis, and IVDMD. Steer gains are also recorded at 28-day intervals. Treatment effects will be evaluated for quality of forage, total seasonal yields of forage, and gain of animals.

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FESCUE TOXICITY IN THE SOUTHEAST

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The toxic effects of tall fescue (Festuca arundinaceae Schreb.) have been recognized for some time (Yates 1962). In cattle, these effects may include fat necrosis, the sloughing off of body extremities (fescue foot), or poorer animal performance than would be expected based on laboratory analyses of the forage (referred to as fescue toxicosis hereafter). It is not known if the causal agent is the same or differs for the above expressions of fescue toxicity. In the southeastern U.S., fescue toxicosis appears to be of considerably more economic importance than either fescue foot or fat necrosis.

Recent research has implicated a fungus in fescue toxicosis. In 1977 Bacon et al. reported the presence of an ergot-producing fungus, Epichloe typhina (Fries) Tul., in tall fescue pastures where fescue toxicosis was known to occur. Recent taxonomic evidence has caused this organism to be reclassified as Acremonium coenophialum by Morgan-Jones and Gams (in press). Shortly after Bacon's results were known, researchers at Auburn University observed that cattle on tall fescue free of A. coenophialum gained approximately twice as much weight as cattle on tall fescue infected with the fungus A. coenophialum (Hoveland et al., unpublished manuscript). These data strengthen the implications of Bacon's data. Examinations of fescue pastures across the Southeast have indicated that most are infected with A. coenophialum.

In order to effectively study the presence of this fungus in tall fescue and its association with toxicity symptoms in cattle, better techniques to identify it had to be developed. Microscopic examination of stem pith as described by Bacon et al. (1977) was limiting in that plants had to be mature enough to initiate stem elongation, and samples could be collected only when stems were available. Researchers at the University of Kentucky developed a system to utilize an enzyme-linked immunosorbent assay (ELISA) technique to both quantitatively and qualitatively determine the presence of this fungus in tall

fescue (Johnson et al., in press). It is very sensitive and is especially well suited to the analysis of large numbers of samples. A simple, rapid, microscopic technique for the detection of _A. coenophialum_ in tall fescue seedlings, seeds, or leaves has been recently developed by E. M. Clark, Auburn University (personal communication). It provides reliable detection with a minimum of equipment and chemicals.

A. coenophialum is apparently spread from site to site through infected seed. No apparent movement of this fungus has been seen over an 8-year period between the two previously mentioned Auburn paddocks even though they are separated only by a fence. However, other means of infection have not been ruled out. Current research at several universities is exploring the possibility of transmission by mechanical means. The possibility of spores being produced on tall fescue (or other hosts) and infecting tall fescue plants also needs to be considered. What does appear evident to date is that _A. coenophialum_ spread in an established tall fescue stand is slow if any spread occurs at all.

The real importance of the _A. coenophialum_-tall fescue association is its apparent effect on cattle performance. Cattle suffering from fescue toxicosis exhibit several symptoms, including excessive salivation, rough hair coats, overexcitability, elevated temperatures, rapid respiration rates, overheating, and most importantly, poor weight gain, as shown in tables 1 and 2. In spite of this evidence, extreme caution must be used when discussing the cause of fescue toxicosis. To date, a direct cause-effect relationship between _A. coenophialum_ and fescue toxicosis has not been established. Only strong correlations between the presence of _A. coenophialum_ and fescue toxicosis symptoms can be offered. Koch's postulates have yet to be satisfied. The toxin(s) involved has yet to be identified.

Table 1.--Average daily weight gains of cattle on tall fescue infected with _A. coenophialum_ and on uninfected fescue, Alabama 1979-81

Tall fescue	Average daily gain kg/day	kg/ha	Stocking rate (No. animals/ha)
Infected	.38	318	4.17
Uninfected	.68	455	3.30

Table 2.--Performance of brood cows and calves grazing tall fescue in Alabama, 1981-1982

Tall fescue	Average daily gain (kg/day)	
	Cows	Calves
Infected	-0.17	.80
Uninfected	.48	1.20

The nature of the interactions involving A. coenophialum, tall fescue, and the affected animal to produce toxicosis symptoms has yet to be defined.

At present, the best method available to producers for control of fescue toxicosis appears to be establishing legumes in tall fescue pastures. Cattle gains on A. coenophialum infected fescue overseeded with legumes have been quite good (Hoveland et al. 1981). In the near future, several tall fescue cultivars that are free or essentially free of A. coenophialum will be available to producers. Much effort is also being spent to identify fungicides and to develop systems that effectively kill A. coenophialum in fescue seed and in established pastures. Current research at Auburn University has tentatively identified several active chemicals, and researchers there are in the process of refining techniques and pursuing registration for such use on tall fescue seed. If fescue toxicosis is caused by the presence of A. coenophialum in tall fescue and if it is transmitted solely via infected seed, either planting noninfected seed or killing the fungus in the seed prior to planting should provide effective long-term control of fescue toxicosis.

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A PROGRESS REPORT ON NITROGEN FIXATION ASSOCIATED WITH GRASSES

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INTRODUCTION

Empirical evidence to suggest that legumes benefit from biological nitrogen fixation (BNF) is overwhelming. This is in contrast to that suggesting a beneficial association between N_2-fixation and grass roots. Early scientific reports indicating benefit to grasses from BNF were based upon Kjeldahl N balance studies of soils. Small, but measurable (15 to 55 kg N/ha/year) gains were reported for soils cropped to grasses (Moore, 1966).

When N fertilizers became abundant and inexpensive after World War II, interest in BNF waned. The increased cost of fertilizer N during the past decade in the U.S. and in developing countries has stimulated renewed interest in BNF associated with legumes and grasses.

MECHANISMS OF BENEFIT TO GRASSES FROM BNF

Free-living N_2-fixing bacteria are ubiquitous in soils (Moore, 1966). Among the more common genera in which all or some species are able to synthesize the enzyme nitrogenase are: *Azotobacter*, *Beijerinckia*, *Clostridium*, *Klebsiella*, *Enterobacter*, *Azospirillum*, and *Derxia*.

Nitrogen fixation occurs during growth and reproduction of the above bacteria. Therefore, a carbon and energy source for the bacteria is essential. Also, nitrogenase is inactivated in the presence of oxygen, indicating the necessity for an anaerobic niche in the soil or a bacterial protective mechanism for the enzyme.

Grasses may benefit from BNF by supplying carbon to bacteria through three mechanisms: (i) carbohydrates released from dead and decaying plant material, (ii) carbohydrates released from living roots, and (iii) an intracellular association between N_2-fixing bacteria and plant root cortical cells where the me-

tabolism of both plant and bacteria are closely related. The first two mechanisms can benefit plants by providing fixed N to nearby roots. This may be of importance in subsistence farming and in undisturbed ecosystems. The third mechanism has been referred to as "associative symbiosis" (Dobereiner and Day, 1976). This type of association could be used by developing countries to partly or completely replace N fertilizers and under highly mechanized farming practices. It is toward discovery and manipulation of the third mechanism which most of the current research in grass associated BNF is aimed.

METHODS FOR DETECTING BNF

The discussion of progress in BNF studies of grasses must include information on the methodology to detect nitrogenase activity. Kjeldahl N balance studies of soils have already been mentioned. Incorporation of $^{15}N_2$ in plant material is definitive proof of benefit to plants from BNF. However, there are only a few reports of attempts to measure N_2-fixation associated with grass roots using this method.

The most widely used technique for measuring nitrogenase activity is measurement of acetylene reduction (AR) activity (Hardy et al., 1968; Hardy et al., 1973). This is an indirect measurement based upon the ability of nitrogenase to reduce an alternate substrate, acetylene (C_2H_2), to ethylene (C_2H_4).

AR activity of grasses has been measured using in situ assays (Tjepkema and van Berkum, 1977), assays of soil-root cores removed from the field (Tjepkema and van Berkum, 1977; Weaver et al., 1980), and excised root assays (Day et al., 1975; Dobereiner and Day, 1976). All three AR methods have some inherent problems, but the most controversial method (van Berkum and Bohlool, 1980) is the excised root assay. Excised roots are incubated overnight under reduced oxygen tension and then exposed to acetylene. Using this technique, extrapolated rates of fixation of up to 2 kg N/ha/day have been obtained for maize (Zea mays L.) (von Bulow and Dobereiner, 1975). Much effort has been spent proving that this technique indicates the potential N_2-fixation rate (Day et al., 1975; von Bulow and Dobereiner, 1975) and proving that this method is a misapplication of the AR technique to measure N_2-fixation (Barber et al., 1976; Tjepkema and van Berkum, 1977; van Berkum, 1980; van Berkum and Day, 1980; van Berkum and Sloger, 1979).

CURRENT CONCEPTS AND PROBLEM AREAS

Evidence of agronomic importance of grass root-BNF associations seems to have made a full circle. There were early observations of small increments to plants and soils, then high hopes for very large inputs, and now experimental values more in line with the original observations. Based upon $^{15}N_2$ uptake, there is evidence that BNF benefits grasses (De Polli et al., 1977;

Dobereiner and Day, 1976; R. W. Weaver, Texas A&M University, personal communication). Rates of uptake that would substantiate high AR rates reported for some grasses are still lacking.

Field studies using preincubated root AR activity indicate possible agronomic importance of BNF associations with tropical grass roots (Day et al., 1975). However, Tjepkema and van Berkum (1977) reported low AR rates for maize using in situ assays in the field. Nitrogenase activity associated with plants growing in wet soils appears to be much higher than that associated with plants growing in dry soils (Tjepkema and Evans, 1976; Vlassak et al., 1973; Weaver et al., 1980). This is probably due to anaerobic conditions which exist in wet soils (Brouzes et al., 1971).

Although links between BNF and photosynthate supply (Dobereiner and Day, 1975), ontogeny of plants (von Bulow and Dobereiner, 1975), and plant genotypes (Dobereiner and Campelo, 1971) have been reported, these still need to be clarified. Efficacy of inoculating plants with N_2-fixing bacteria (Wood et al., 1981; Wright and Weaver, 1982) needs more investigation and plant responses to BNF must be differentiated from responses to bacteria-produced plant growth regulators (Brown, 1976). Further work on the effects of fixed N on nitrogenase activity associated with plant roots (Dobereiner and Day, 1975; Wright and Weaver, 1981b) is necessary.

The ecology of N_2-fixing bacteria associated with grasses is another area that needs further study. *Azospirillum* is often found associated with grasses in the tropics (von Bulow and Dobereiner, 1975; Dobereiner and Day, 1976). *Enterobacter* and *Klebsiella* are often found associated with grass roots in temperate climates (Sherman et al., 1979; Wright and Weaver, 1981a).

Azospirillum is an organism which fixes N_2 under microaerophilic (slightly reduced) conditions rather than completely anaerobic conditions. This organism may reside within cortical root cells (Dobereiner and Day, 1976) which suggests that associations between this bacterium and grass roots would be of great agronomic value. However, there is insufficient evidence to indicate that this association is exploitable at this time.

To study grass root-bacteria associations and address some of the above problems a model plant-bacteria system for measuring BNF needs to be discovered. The system must be manipulatable and give reproducible results.

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FORAGE EVALUATION TECHNIQUES

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We do research to learn something about the universe, or, at least a small part of the universe. In mission-oriented research, such as generally done by the State Agricultural Experiment Stations or the USDA-ARS, we generally stress that what we learn will have societal value. For this presentation, I shall attempt to tie together the growth in our knowledge of forages with the history of forage quality evaluations, in terms of expected response by animals, as a regional effort in the Southern U.S. In tracing the development of a regional effort, one becomes aware of some significant successes, outright failures, and continuing frustrations.

SOUTHERN REGIONAL RESEARCH PROJECT S-12: Subproject I

The first Southern Regional Research Project dealing with forages was identified as S-12. Subproject I (1954) was entitled "Pasture and Forage Evaluation Techniques" to emphasize that this part of the regional research effort was primarily concerned with techniques. The stated objectives were: (1) to develop improved methods of agronomic evaluation of species, strains, and selections of forage plants at the small-plot stage; (2) to develop improved methods of accurately determining the value of forage plants and mixture of plants in terms of production of animals or animal products; and (3) to determine the correlation between animal and nonanimal evaluation methods.

SOUTHERN REGIONAL RESEARCH PROJECT S-45

To better serve the need of the Southern Region and to allow the varied professional interests involved to make a more significant contribution, three new regional projects were initiated in 1958 and S-12 was terminated. Subproject I of S-12 was replaced by a new Southern Regional Research Project S-45 entitled "Nutritional Evaluation of Forage Crops." The objectives of the project proposal placed emphasis on the develop-

ment of methods and techniques. These were (1) to determine chemical and physical properties of forages that are related to animal response; (2) to develop methods for predicting nutritional value of forage crops under known intake conditions; (3) to develop methods for measuring intake and digestibility of grazed forages; and (4) to develop methods for predicting forage intake. Interest in measuring the digestibility and intake of forage by freely grazing animals was high at the time, as it followed the publication by Reid and coworkers (1952) of a technique utilizing an internal forage marker (chromogen) and an external marker (chromic oxide) ingested by the animal.

Two other regional projects initiated simultaneously with S-45 were S-46 (forage breeding) and S-47 (forage physiology). Neither endured as long as S-45, however.

In their review of the S-45 project proposal, the Committee of Nine (a committee of nine persons elected by and representing the Directors of the State Agricultural Experiment Stations) offered the following: "It is urged that the technical committee develop and maintain coordinated working principles. The committee should consider concentrating work on a limited number of key species of plants and animals." The general response of the S-45 technical committee at the time may be summed up with the quote, "We have gone over this time and time again but it keeps coming back. I would appreciate some suggestions for convincing these people that we are studying techniques and not forages."

A degree of success was realized when, after some years, the course initially suggested by the Committee of Nine was followed. Little progress was made by the S-45 Regional Project on techniques as envisioned originally in 1958. Research on most concepts prevalent among the technical committee at the time is now at a minimal level or has been abandoned altogether.

A landmark development did occur during the early years of the existence of S-45, however. It was in this time period that H. L. Lucas (1964) advanced the "nutritive entity" concept. A nutritive entity, as defined by Lucas, is a "nutritionally ideal" chemical fraction with relevant invariant properties with respect to digestibility, the absorbability and volatility of digestive end-products, and the nutritive value of the absorbed end-products after entering the body.

First Revision of Project S-45

With the revision of the S-45 Regional Research Project proposal in 1965, both the title and objectives again emphasized methods. The project proposal, entitled "Development of Methods for Relating Forage Properties to Intake and Digesti-

bility," had the following objectives: To develop methods for relating chemical and physical properties of forages to (1) voluntary intake, (2) rate and extent of digestion, and (3) rate of passage.

While little progress was made on the development of methods with the 1965 revision, factors affecting both digestibility and intake of forages were elucidated. Digestibility was found to be affected by, among other things, crude protein, the composition of the cell wall, level of feed intake, and water restriction (1970). The Tilley-Terry *in vitro* procedure with modifications was found to be one of the better laboratory methods for predicting *in vivo* digestibility but not always sufficiently accurate for all southern (tropical) forages. Likewise, the Van Soest predictive equation using acid-detergent fiber and lignin was called into question when used to predict the digestibility of tropical forages.

Forage intake was found to be influenced by ambient temperatures, cell wall content and composition (but in a poorly understood way), and physical state of the forage (grinding, pelleting, etc.). Little, if any, progress was made in relating chemical and/or physical properties of forages to voluntary intake.

Second Revision of Project S-45

The 1970 revision of S-45 represented a major shift in emphasis for the technical committee. The first meeting of the S-45 technical committee held for the purpose of again revising the project statement was in conjunction with the National Conference on Forage Quality Evaluation and Utilization at Lincoln, Nebraska, on September 3 and 4, 1969. The impact of this conference on the work conducted by those associated with the S-45 Regional Research Project and under the auspices of this project in the years following this conference seems evident. It illustrates the value of such a national conference.

The title of the S-45 Regional Research Project, as revised for the period of July 1, 1970, to June 30, 1975, was "The Relationship Between Properties of Southern Forages and Animal Response." The objectives were as follows: (1) characterize selected southern forages with regard to chemical properties and *in vitro* dry matter disappearance; (2) determine the following animal responses to selected southern forages: [a] voluntary intake, [b] nutrient digestion and absorption, [c] energy utilization, and [d] rate of gain; and (3) evaluate forage characteristics and animal responses as predictors of animal productivity of southern forages.

There was a growing realization that the warm-season southern grasses (tropical) were different than nonsouthern (temperate)

grasses, particularly with respect to the amount and the composition of the cell wall. It would seem fair to say, however, that the biochemical pathway for the formation of end-products of photosynthesis (C_3 vs. C_4) was poorly understood by the members of the technical committee. Nevertheless, as suggested by the Committee of Nine in 1959, the technical committee did seek to understand what was different about southern forages. The attitude "The regional project should reflect what the states are doing" was no longer pervasive.

The major contribution of the S-45 Regional Research Project following the 1970 revision was providing data that furthered our understanding of the differences between several classes of forages. Even so, our knowledge is far from complete. There are some noteworthy differences that seem to be reasonably reflected by differences in animal performance. Legumes, for example, contain more neutral detergent solubles (NDS), which are almost totally digestible, than grasses do at similar stages of maturity. The cell walls (neutral detergent fiber or NDF) of legumes have a much lower hemicellulose and a higher lignin content (% of cell wall) than grasses. Temperate grasses are generally higher in NDS and lower in NDF content than tropical grasses at similar stages of maturity (though, admittedly, stage of maturity is not always easy to define). Similarly, temperate annual grasses are generally higher in NDS and lower in NDF than temperate perennial grasses, and tropical annual grasses are generally higher in NDS and lower in NDF than tropical perennial grasses at similar stages of maturity. Expressed as a percent of cell wall, the cell walls of some tropical grasses, e.g., *Cynodon* sp., contain more hemicellulose than cellulose, but this does not appear to be universally true, e.g., *Digitaria* sp.

These differences in composition together with the results of digestion and intake studies plus performance of animals in pen feeding and grazing trials have suggested a scheme of categorizing the several classes of forages which seems to reflect expected animal performance (Riewe 1976). Based upon their experiences in temperate climates, R. L. Reid (1981) and P. J. Van Soest (1982) have proposed modifications suggesting better animal performance on grasses than that suggested by Riewe. Modifications for the latitude and perhaps altitude at which the forage is grown may be in order. Some of the highest gains for cattle grazing coastal bermudagrass, for example, have been reported from North Carolina, about as far north as this species may be expected to grow.

SUCCESSES

The major success has been in better understanding differences in the chemical and physical composition of forage classes and thereby a proper appreciation for the limitations as well as

the potential for animal production on tropical forages. There is no question in my mind that our understanding of so-called southern forages has been greatly advanced because of the Van Soest fiber analysis method.

Some progress (more limited than we would like) has been made in developing methods for predicting nutritional value of forage crops under known intake. The Tilley-Terry *in vitro* system, generally modified, is a widely used biological system for estimating digestibility of forages. Determining the correlation(s) between component(s) of cell wall and digestibility, intake, or digestible dry matter intake for predictive purpose is most often an empirical procedure. As such, this method of predicting the nutritional value of forages is subject to the pitfalls generally associated with empirical methods. This is not to say that such methods are not useful but rather that care must be exercised in using such methods.

A major development during the 1970's was the use of infrared reflectance spectroscopy for the nondestructive analysis of feeds and forages. The system does not represent a breakthrough in relating physical and chemical properties of forage to the nutritional value of forages. It is rather a shortcut (rapid) for estimating the chemical fractions known to be involved in the availability of nutrients in forages, i.e., cell wall, lignin, protein, *in vitro* digestibility, etc. It is useful for rapidly screening the large number of samples that might be involved in forage breeding programs or in extension forage testing programs. It is not adapted to basic work on the physiochemical composition of forages.

FRUSTRATIONS

The S-45 technical committee, along with other researchers, was generally frustrated in attempts to develop methods for rapidly measuring the amount and digestibility of forage consumed by grazing animals. Worldwide, much time and millions of dollars have been spent in this effort, yet little progress has been made in the past twenty-five years. In the meantime, major advances have been made in our understanding of the plant/animal complex. This progress has been achieved by bringing together the skills of many different disciplines. To view the ability to measure the amount of forage consumed by freely grazing animals as absolutely essential to increased understanding of the plant/animal complex may be nothing more than an inability to see the forest because one tree blocks our view.

If the view is held that the ability to measure the amount of forage consumed by grazing animals is critical, then it seems reasonable to ask, "In what way?" One answer is that with pasturage in short supply, as may be the case with advanced lines in forage breeding programs, it is highly desirable to

relate a short-term animal response to attributes of the sward (mass, density, chemical composition, physical structure, etc.). Animal weight changes are generally too variable in the short term to be useful. The ability to measure the amount of forage consumed by grazing animals would be useful in validating animal responses to attributes of the sward (Blaser et al. 1969). Such a validation has obvious usefulness in the mathematical modelling of the plant/animal interface.

LIMITATIONS

A limitation of the work done under the auspices of S-45 after the second revision was the limited number of tropical forages involved. Only three perennial grasses (Pensacola bahia, coastal bermudagrass, and pangola) and two cultivars of one annual grass (sorghum x sudan) were involved. This may have been too restrictive to gain a good understanding of the physiochemical composition of the cell wall of tropical grasses.

Another qualitative factor not addressed (rather largely ignored) is the relationship of carotenoids in forages to yellow fat in cattle slaughtered off pasture. If any significant progress is to be made in developing beef-finishing systems on forages alone, this question must be addressed. While yellow carcass fat is a major marketing problem, simply educating the consumer to accept yellow fat would not be enough. Historically, yellow carcass fat has been associated with carcasses from animals reaching slaughter weights at a relatively slow rate. It has been demonstrated that full feeding of high-energy grain rations 90 to 120 days before slaughter gives assurance of quality beef equal to or greater than final USDA carcass quality grade. The same may be true for finishing young cattle (younger than 30 months) on pasture. But the consumer would have to be provided some kind of assurance that beef with yellow fat is reasonably tender and flavorful. Although yellow carcass fat is admittedly a marketing problem, little is known about the chemistry of deposition and removal of carotenoids from fat. It should be recognized as an important researchable problem in forage quality in the South. Few questions regarding forage quality have greater economic significance.

SUMMARY

Very significant progress has been made in understanding the plant/animal complex in the past quarter century. Much has been learned about why ruminants perform differently when grazing or being fed the several classes of forages. The role of the cell wall in determining the performance of animals consuming forages is better understood. There is a much greater appreciation of the relation of the performance of grazing animals to attributes of the sward (mass, density, canopy

structure, physiochemical characteristics, etc.). Yet, much remains to be learned if grasslands in the world as well as in the South are to serve society well.

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GRAZING MANAGEMENT [1]

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I. IMPORTANCE OF MANAGEMENT

The implementation of excellent grazing management practices to compromise animal products/animal and /hectare for suitable economic returns for producers at acceptable consumer prices is a profound challenge. Grazing management for desirable animal performance is especially important in southeastern United States because forage species and environmental factors often depress digestible dry matter intake (DDMI) and output/animal (Op/A).

Environmental factors depress or improve forage digestibility and intake for given morphological characteristics (leaf-stem ratios or growth stages). When grazing, Op/A is highest during cool temperature winter-spring seasons, lowest during the warm temperature summer season, and intermediate during the cool autumn. High temperatures cause increases in cell wall materials in forage leaf and stem tissues which lowers digestibility. As cell wall contents increase, the added amounts of indigestible cell wall materials in the rumen cause the ruminant to eat less and produce less during warm than cool temperature periods.

Temperatures also influence the adaptation of forage species and animal production potentials. With warm temperatures, as for the lower latitudes, tropical species replace temperate forages except for winter grazing. With herbaceous perennials, tropical grasses and legumes are higher in cell wall materials than forages of temperate origin; hence, the latter with highest DDMI

[1] A detailed presentation with literature citations is given in Tropical Grasslands 16, 1982.

augment Op/A as compared to tropical or semi-tropical species. It is known that the highest Op/A occurs with winter grazing in the southern region. The higher DDMI in the winter than the summer season is associated with utilizing temperate winter annuals and perennials during the cool winter season. Cool as compared to warm temperatures per se also favor production of ruminants.

Organic nitrogen compounds and nonstructural carbohydrates are components of cell contents which promote Op/A because these materials are around 98% digestible. Perennials from temperate regions are higher in soluble carbohydrates and cell content materials than those from tropical areas. Cool as compared to warm temperatures or some moisture stress that restricts growth also increases soluble carbohydrates and animal performance (DDMI and Op/A).

Nitrogen fertilization causes large increases in animal products/ha but does not usually influence Op/A when available pasture (AP) and growth stage (GS) are controlled. Nitrogen fertilization increases protein fractions but reduces soluble carbohydrates. Cell contents with low and high N fertilization remain similar; also, rates of N application do not usually alter leaf-stem ratios nor cell wall contents. Thus, DDMI and Op/A are similar when grazing pastures with low or high N when AP and GS are near constants. However, with canopies low in density, as with course tropical species, N fertilization during early growth increases the density of canopies and DDMI and Op/A. Such favorable effects on canopies from N fertilization are attributed to larger bites and reductions in grazing time, thereby increasing DDMI and Op/A. However, such benefits from N may later be nullified because liberal N stimulates rapid growth and steminess, unless canopies are controlled by grazing management.

When utilizing any herbaceous forage, low energy intake (DDMI) is the primary factor that restricts Op/A and the efficiency of converting forage to animal products. Ruminants require 8 to 14 times more digestible energy than digestible protein. If a steer is to gain 300 kg to produce a 450 kg marketable carcass, a 0.25-kg daily gain will require 1200 days and 7320 kg forage dry matter and 652 kg crude protein. If DDMI intake is improved to gain 0.5 kg daily, dry matter and protein requirements will be reduced 61 and 67%, respectively. In addition, capital investments will be reduced to 600 days. Higher DDMI values cause additional sharp improvements in animal products per unit of forage dry matter and shorten periods of capital investments.

II. ENERGY INTAKE IN GRAZING MANAGEMENT

Energy intake (DDMI) is directly associated with Op/A with

responsive ruminants. Available pasture (AP) at given time is directly allied with Op/A when leafiness or growth stage (GS) is constant. As GS shifts from leafy to stemmy morphologies, DDMI and Op/A decline when AP is constant.

The nutritional needs of animals vary with classes and cycles of production of ruminants. Highest to lowest nutritional needs for different ruminants may be categorized as follows: high-producing lactating dairy cows, calves, weanlings, finishing cattle for market, growing replacements. The nutritional needs of beef cows are variable--medium during a month or two before to three or four months after calving and low during the other periods of production. The medium nutrition coincides with the cycle when milk production is essential for calves and to encourage oestrus and conception.

III. INTEGRATED MANAGEMENT

In grazing management for livestock farming or research evaluations, it is of paramount importance to control and allocate the needed nutrition to classes of ruminants and cycles of production for entire enterprises such as milk production, efficient calf raising, growing of replacements and stockers or fattening for market. This is done by controlling and managing AP and GS.

Integrated forage-animal management systems where outputs/ animal and per hectare are wisely compromised for favorable economic returns should be developed for different environments in the south. The choice of livestock enterprises will vary with ecological environments (seasonal yield and quality of forage from adapted plants in the varying soil-biotic-climatic conditions in the south). Adaption of ruminants and markets are significant interplaying factors. Integrated management for entire phases of beef cattle, dairy and sheep enterprises with all-year grazing and a minimum of harvesting and "hand" feeding should be planned and tested by research and extension specialists to hasten progress. High-energy forages such as grain corns and sorghums should be reserved for responsive ruminants with high digestible energy requirements as for milk cows, fattening calves or young stock.

IV. RAISING CALVES EFFICIENTLY

The efficiency of converting pasture to calf production can be improved by maintaining high nutrition for calves and variable nutrition for their dams by controlling DDMI via AP and GS. Calves respond to food in addition to milk. For example, nursing calves from about 4-7 months old when weaned gained around 150 g per day when restricted to milk as compared to about 900 g when supplemented with corn silage. Gains of

calves fed corn silage *ad lib* were not influenced by nutrition of their dams (fed to gain 250 or lose about 500 g daily). The cows had good nutrition before calving until four months after calving to furnish milk for young calves and encourage oestrus. In a grazing experiment with low AP for cows and calves, calves creep grazing into a pasture with a high AP gained 40% more than the calves without creep grazing.

A grazing experiment with constant stocking rates for systems, variable stocking within systems and creep grazing controlled and allocated the quality and quantity of AP for cows and calves. One system with two stocking rates (0.68 and 0.81 ha per cow and calf) had 3 paddocks: 1 paddock 56% of the area in bluegrass-white clover was used for spring-late autumn grazing and 2 paddocks of equal size in tall fescue-red clover were used for hay in spring, summer grazing, accumulating forage after mid-summer for late autumn and winter grazing, and for creep grazing at any date. Flexible integrated management was dependent on climate, nutritional needs of animals, and controlling growth stage, botanical components and persistence of plants. During dry spring seasons, only one paddock was used for hay. Hay was fed to the cows and calves during winter when snow cover prevented grazing.

Creep grazing gates were placed in fences between paddocks to creep graze any paddock with a high AP whenever the pasture where cows and calves grazed together had a low AP. Excellent pasture utilization by grazing to a very low AP with cows was enforced. Whenever cows grazed pastures to a very low AP that could depress regrowth, raise soil and canopy temperatures due to poor sward insulation, or inhibit water infiltration, the cows were advanced to the creep-grazed pasture. The cows with calves then grazed together. When grazing to a medium AP, the calves began to creep graze the next pasture as creeps were open for grazing at all times. This management enforced excellent utilization, minimized over-grazing and damage to pastures, while controlling and providing the differential nutritional needs of cows and calves.

The liveweight gains of calves were similar for the 2 stocking rates, daily gains averaging 1.02 kg per calf and weaning liveweights were almost identical, 253 and 254 kg per calf. Controlling and maintaining high AP values for calves at the higher stocking rate made it possible to increase liveweight gains per ha by 19% without sacrificing calf gains. The targets of weaning calves at 250 kg, obtaining high gains/ha, and maintaining high calving percentages were realized. The cows restricted to the systems all year without shelter or grain supplements maintained excellent health. Integrated management of animals and pastures has tremendous possibilities of improving the efficiency of animal production.

MANAGING TROPICAL GRASS PASTURES TO MAINTAIN LEGUMES

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The importance of legumes in pastures relative to animal daily gain and cost per unit of total digestible nutrients (TDN) produced is generally well understood. The problem of retaining acceptable legume-grass mixtures in temperate pastures is complicated and not easily achieved. The problem is even greater when legumes are grown in mixture with tropical or subtropical grasses that have erect growth habits and attain heights of 1.5 to 2.5 meters if left unchecked.

A discussion of this topic seems predicated on examining some of the more basic aspects of growth, morphology and physiology. The likelihood of one species to dominate in a two-species mixture must be related ultimately to growth. This depends on each species' net capacity of CO_2 assimilation, resulting in increased foliage extension and size. Such capacity will be altered for each species depending on the defoliation frequency and intensity imposed. Growth can be expressed as a rate (dry wt. added relative to dry wt. present/unit of time) phenomenon or as dry wt. added/unit leaf area/unit time (mg/cm^2/minute). The latter is termed the net assimilation rate (NAR). Total assimilation then is equal to the NAR X leaf area. Generally, with initiation of growth (initial growth or regrowth) the NAR is high and leaf area is small. As growth proceeds the NAR declines and leaf area increases.

It is also important to note that plants with greater optimum leaf area index (leaf area/unit land area) produce, over time, the most dry matter while plants with a lower optimum LAI produce less dry matter, but reach their maximum growth rate sooner. However, the former plants may still produce more dry matter over time even if growing below their optimum LAI. This situation, in essence, operates in a legume-grass mixture. Individual leaves of legume plants are generally displayed better for maximum light interception and a lower LAI is optimum for maximum growth. For example, clover leaves are displayed more parallel to the sun than are ryegrass leaves and

clover has an optimum LAI of about 3.5 compared with 7.1 for ryegrass. Both factors are important and contribute to the competitiveness of the legume in mixture with a grass.

Physical factors as radiation, CO_2 concentration, temperature and moisture; physiological factors as root reserves and location of growing points when defoliation occurs; and other factors as insect and disease infestations are all important in altering plant growth. Their impact on plant growth are further complicated by competition. The potential of growing legumes with tropical or subtropical grasses, in essence, places low-photosynthetic-capacity plants (C_3) in competition with high-photosynthetic-capacity (C_4) plants. These two groups differ appreciably in their response to many of the above factors.

The major differences that would most likely alter competitiveness are noted in Table 1. The high-photosynthetic-capacity plant has a greater photosynthetic rate when grown at its optimum temperature (appreciably greater than the low-capacity group). Associated with the high rate is less sensitivity in terms of leaf saturation at full sunlight, lower CO_2 compensation concentrations, less inhibition to O_2 pressure and lower nitrogen concentrations for maximum growth. This is all reflected in greater water use efficiency in terms of grams of water used/gram of dry matter produced.

In general, in cool, moist environments the difference between

Table 1.--Differences between low- and high-photosynthetic capacity that might alter competitiveness in a mixture[1]

Item	Photosynthetic capacity	
	Low	High
Photo. in full sunlight (mg of $CO_2/dm^2/LA/h$)	15-35	40-80
Opt. temp. for photo. (C°)	10-25	30-45
Photo. response to increased sunlight	Sat. at 1,000-4,000 ft. cnd	May not sat. at full sunlt
CO_2 Compensation conc (ppm)	30-70	0-10
Oxygen pressure	Inhibition (above 1%)	No effect (0 to 100%)
Nitrogen use efficiency [N (%) for max RGR]	6 to 7	3 to 5
Water required (g/g dry matter)	628	301

1/ Adapted from C. C. Black. 1971. Advances in Ecological Research. Vol. 7; 87-114.

C_3 and C_4 plants would probably be small while a stress environment that involves high radiation, high temperature and limited water would favor C_4 plants. Such conditions are descriptive of the summer period in much of the southern and eastern USA.

Harvesting tropical or subtropical grasses to maximize dry matter yield will generally preclude a grazing situation. In this case, viny legumes that will grow along the upper surface of the grass canopy may compete and make a contribution in terms of nitrogen fixation and improved nutritive value.

A grazing situation is quite different and further complicated by animal factors such as trampling and defoliation injury, preferential grazing and waste disposition. Injury from trampling and defoliation is somewhat subtle as it allows for higher occurrence of diseases over time while the latter two have more direct bearing on competition.

Preferential defoliation of a broad-leaved plant, as a legume, frequently causes it to take on a more erect growth habit and subsequently makes it more subject to later preferential defoliation. Several cycles of preferential grazing deplete root reserves and reduce regrowth. The weakening of plants, whether from preferential grazing or simply from repeated defoliation allows the intrusion of less weakened plants in a mixture to intercept more light and compete better for nutrients. Such plants soon develop greater capacity to exploit nutrients and light and become even more competitive.

In actual practice, the competitiveness of presently grown legumes (temperate species) with tropical or subtropical erect-growing grasses may be better than anticipated. The temperate legumes initiate growth earlier and the herbage height will likely be maintained through grazing at 10 to 20 cm. The legume will dominate early and the canopy height will likely approach the optimum LAI for maximum legume growth but much below the optimum LAI for maximum grass growth and place the grass at a disadvantage.

These relationships will become more clear as interest increases in the eastern third of the US in using subtropical, perennial grasses in pure stands and in mixture with legumes.

FORAGE BREEDING AND SELECTION

Glenn W. Burton

U. S. Department of Agriculture

Livestock production in the South has improved greatly since the turn of the century. Then most of the cattle grazed the native range, a mixture of wiry, unpalatable species that grew under the pine trees. Twenty to 30 acres were required to feed a cow 12 months. The calf crop was less than 50%, the weaned weight of the calf was about 250 pounds, and liveweight gains per acre ranged from 8 to 12 pounds. Better forages, the product of plant breeding plus the addition of fertilizer and good management to enable them to reach their potential, helped to make the change. The evolution of pasture production on the South's sandy soils as measured by grazing studies conducted at the Coastal Plain Station is shown in the following table:

Table 1.--Pasture Evolution on the South's Sandy Soils

Feed Source	Yearly Liveweight Gain (lb/acre)
Native range	8
Native range burned	12
Carpet grass	30
Carpet grass + annual lespedeza	60
Common bermudagrass	80
+ 30 lb N/acre	150
Coastal bermuda + 30 lb N/acre	275
+ 200 lb N/acre + P & K	675
+ 140 lb N/acre + P & K	485
Coastcross-1 + 140 lb N/acre + P & K	745

There have been many forage breeding programs in the USA. Let me cite some of our work at Tifton as an example of what such programs can do.

Breeding better forages requires good germplasm, proper objectives and methods, adequate support, assistance from other disciplines, particularly animal science, time, and hard work. Germplasm collections may produce superior forage varieties without modification. Pangola grass and Argentine bahiagrass are good examples. Such collections must be evaluated, however, to isolate the good ones.

For many years increased yield and dependability were our most important objectives. They determine costs and the ultimate fate of the cow and her keeper. The forage variety that fails to increase yields of animal product will not enjoy much success. Coastal bermudagrass, a vegetatively propagated F_1 hybrid, was released in 1943 because it would produce nearly twice as much forage as common bermudagrass. It took 20 years of research, however, to demonstrate its full potential.

Today, improved quality is our number one objective. The importance of quality can be demonstrated by comparing Coastal bermuda with Coastcross-1, an F_1 hybrid between Coastal and a bermudagrass from Kenya. Both grasses yield the same quantity of dry matter, but Coastcross-1 dry matter is 12% more digestible. A 4-year grazing experiment conducted with the help of animal scientist B. L. Southwell proved that the better quality (digestibility) of Coastcross-1 enabled it to produce 40% better average daily gains (ADGs) and 40% more liveweight gain per acre (LWG/acre). These results explain why Warren Monson on our team analyzes the _in vitro dry matter digestibility_ (IVDMD) of some 10,000 of our forage samples each year.

Because the leaves are the top-quality portion of a plant, increasing the leaf percentage of a forage will usually increase its quality and the performance of animals consuming it. Tifleaf 1 pearl millet is a good example. Introducing the recessive d_2 gene into the parents of this F_1 hybrid reduced the height of the mature plant 50%, increased the leaf percentage in the preflowering stage 60%, and significantly increased ADGs and LWG/acre over tall millets from 13% to 33%.

Increased efficiency in use of growth factors is another important objective. The ability of Coastal bermudagrass to produce much more forage per pound of fertilizer applied has contributed to its success. Its greater efficiency in water use has enabled it to produce feed for livestock during droughts when many other grasses, including common bermuda, have turned brown.

Increasing resistance to the many diseases, insects, nematodes, and other pests that cut yields and destroy forage leaves will always be an important plant breeding objective. Rust is a serious disease of many forages that cuts yields

and reduces their palatability and digestibility to the extent that the ADGs and LWG/acre of cattle grazing rusted forage are also reduced. Coastal and Tifton 44 bermudagrasses are immune to rust. Fortunately many of the promising new hybrids between Tifton 44 and the rust-susceptible Callie bermudagrass are also immune to this serious disease.

Increasing the winter hardiness of Coastal bermudagrass by crossing it with a cold-hardy bermudagrass from Berlin, Germany, produced Tifton 44, which can be dependably grown much farther north than Coastal.

Eight different plant breeding methods have been used in the forage breeding program at Tifton. Most of these have enabled us to use hybrid vigor to increase forage yields.

Recurrent Restricted Phenotypic Selection (RRPS) is a modified form of mass selection that has been four times more efficient in increasing forage yields of Pensacola bahiagrass. We believe it will become increasingly important as a breeding method for many forages.

Success in the breeding of forages requires precise screening of thousands of plants in a uniform environment. Forage breeding will do well to continually search for better screening methods.

Time and a trained eye can select the better plants growing in a uniform environment. But replicated precise clipping tests will be required to separate the best from the better plants. Warren Monson determines the IVDMD of the forage taken from each plot of such tests every time the plots are cut. Three years of such testing with an average IVDMD of 75 samples from each entry goes a long way toward separating the best from the better plants.

A new forage must finally be assessed by the kind of animals that will ultimately consume it. This requires the assistance of the animal scientist. The excellent cooperation that we have had from the animal scientists at Tifton across the years has contributed greatly to the success of our forage breeding program.

Certainly the area of adaptation must be established. This calls for the assistance of forage agronomists wherever the improved forage may be grown. Again we must thank these men for their invaluable assistance. Thirty agronomists in 14 states helped us to learn where Tifton 44 bermudagrass can be used dependably.

Finally the new forage varieties must be managed properly. Roy Blaser once said, "I can make or break any forage by the

way I manage it." Coastal bermudagrass (a single genotype), uniformly fertilized, cut and wagon-dried at 4, 8, and 13 weeks of age, gave ADGs of 1.18, 0.88, and 0.00 pounds, respectively, when fed to dairy heifers by Marshall McCullough at Experiment, Ga.

Better forages can be bred if the proper requirements are met. They are good germplasm, proper objectives and methods, adequate support, assistance from other disciplines, particularly animal science, time, and hard work.

PROGRESS WITH RECURRENT RESTRICTED PHENOTYPIC SELECTION FOR YIELD IN DIPLOID PENSACOLA BAHIAGRASS

Glenn W. Burton

U. S. Department of Agriculture

Recurrent restricted phenotypic selection (RRPS) is mass selection modified by restrictions that make it up to four times more efficient. Research begun on the method in 1961 was motivated by the conviction that the variable and frequently poor results obtained with mass selection for yield could be improved.

Pensacola bahiagrass (_Paspalum notatum_ var. saure) is a well-adapted, perennial, warm-season grass that occupies several million hectares in the Southeastern United States. It is a diploid (2n = 20) that reproduces sexually. Single seedlings or propagules spread 30 to 45 cm per year by short stolons to form a dense sod. Most plants are highly self-incompatable but will produce a few seeds when selfed. Flowering and seed production usually continue for two to three months during the summer.

Eight cycles of RRPS have given a consistent first-year spaced-plant forage-yield increase of 16.4% per cycle. One cycle per year is now possible. Cycle 6, compared with commercial Pensacola bahiagrass as the control, yielded 91% more in the spaced-plant progress test and 84% more in a seeded small-plot test. Cycle 4 yielded 16% more liveweight gain than the control in a 3-year replicated grazing trial, which was expected based on forage yields from a small-plot clipping test. In a seeded test, cycle 6 yielded two-thirds as much as F_1 hybrid 2 x 3 in the first year and almost as much as the hybrid in the unusually dry second year. RRPS that increased the cycle 6 forage yield 84% over the control in seeded plots did not significantly reduce the _in vitro_ dry matter digestibility of the forage.

IMPROVED RRPS RESTRICTIONS

1. Selecting visually the 5 best plants in each 5 x 5 spaced-plant grid 100 days after setting in the field reduces

soil heterogenity effects, facilitates visual selection, and permits 1 cycle per year.

2. Saving 20% of the 1000-plant population for the next cycle retains genetic variability, delays loss of vigor due to inbreeding, and reduces the likelihood of overlooking high-yielding plants.

3. Intermating selected phenotypes for the next cycle in the laboratory RRPS polycross imposes paternal as well as maternal selection and doubles the mass selection rate of advance.

4. Intermating three flowering heads per selection in close proximity in the RRPS polycross insures equal parental input, maximizes gene recombination, and saves one season frequently used to plant and harvest a polycross nursery.

5. Transplanting the seven largest seedlings in 100 from each polycrossed selection improves seedling vigor, gives a 20,000 $\pm$ seedling population, and screens the equivalent of all possible recombinations from the 200 selections $n \times (n-1) \div 2 = 19{,}900$.

6. Using two spaced plant yields, winter survival, spring vigor ratings, and other notes taken after the polycross is made to discard the polycross progenies of the poorest 35 selections gives a full year of selection and improves the field-planted population.

7. Recording randomized seedling placement of one seedling from the progeny of each of the 165 polycrossed selections in each of six blocks permits statistical analysis of data and enables pedigree studies.

8. Improving all cultural practices with emphasis on uniformity facilitates effective phenotypic selection and helps complete 1 cycle per year. To demonstrate their yield potential and produce enough heads for the RRPS polycross the first year, seedling plants must be given optimum growing conditions. This means insuring that water and plant nutrients are always adequate and space is not limiting. Using 5-cm pots to grow large seedlings in the greenhouse and setting them 75 x 75 cm apart in the field provides the necessary space. Plants set 60 x 60 cm apart in the field failed to produce enough heads for the polycross in the first season.

A detailed account of the results presented in this talk and summarized here has been prepared for publication in Crop Science.

SELECTION OF ALFALFA FOR GROWTH IN HIGHLY WEATHERED, ACID SOILS

J. H. Bouton

University of Georgia

Acid soils, usually containing toxic levels of Mn and Al, are prevalent in many areas of the Southeastern United States. In the Piedmont region of the upper South, these acid soils are also highly weathered, and due to past cropping practices, severely eroded. Growing productive alfalfa (*Medicago sativa* L.), a forage legume which is very sensitive to acid soil conditions, is thus a problem in these soils. Liming and proper fertilization will overcome acid soil problems and increase yield of alfalfa. However, these practices rarely affect subsoil acidity, thus restricting the strongest botanical feature of the crop--its deep taproot.

Although the Southeast is a high-rainfall region, it is also characterized by poor rainfall distribution. Most of the rain from May to October comes as intense but scattered showers causing periodic droughts in many areas within the region. Therefore, when this poor rainfall distribution is coupled with alfalfa's poor root distribution into acid subsoils to extract water, yield can be reduced drastically during these droughts. In the future, it may become possible to inexpensively lime and fertilize acid subsoil, but right now, it is not. Therefore, a way to overcome the problem is to use plant breeding and genetics to develop alfalfa cultivars which are productive over a range of soil conditions (both acid and nonacid), yet able to penetrate acid subsoils to extract subsoil moisture. This strategy is encouraging, given reports stating that toxic element tolerance is a heritable trait in alfalfa (Oullett and Dessureaux 1958, Devine et al. 1976).

A selection program was begun on a base population of 10 cultivars to develop an alfalfa germplasm productive in acid soil conditions (Brooks et al. 1982). Selection was accomplished in a Cecil clay loam soil (pH = 4.8, native P and K levels of 7 and 116 kg/ha, respectively, and containing toxic levels of

Mn and Al). Concurrent with this acid soil selection, another germplasm was selected from the same base population for productivity in the same soil which had been limed (pH = 6.2) and fertilized (P and K applied at 40 and 52 µg/g soil, respectively). This germplasm selected in limed soil thus provided a good control for comparisons on the amount of gain produced through selection for both general productivity and acid tolerance. After selection for two cycles, testing was conducted in the greenhouse and field to compare the acid-soil-selected and lime-soil-selected germplasms under a variety of soil pH and fertility conditions.

In one greenhouse pot experiment (Brooks et al. 1982), the two germplasms were grown in the acid Cecil soil at two soil pH levels (4.8 and 6.2) and two P levels (addition of 0 and 48 µg P/g soil). A basal application of K, Mg, B, Mo, Zn, and Cu was added to each treatment. Tissue analyses for each soil testing condition are presented in table 1.

These tissue analyses demonstrate the following: 1) the deficiency of P where none is added at both soil pH levels, 2) the toxic levels of Al at pH 4.8 and the trend toward neutralization of Al by either liming to pH 6.2 or an addition of P, and 3) the toxic levels of Mn at pH 4.8 and the neutralizing effect of liming on Mn, but the poor ability of P to neutralize Mn. The topgrowth yields of the two germplasms in this experiment are shown in table 2.

Table 1. Concentration of P, Al, and Mn in the tissue of alfalfa (pooled by germplasms) when grown in a Cecil soil in greenhouse pots at two soil pH and two P levels. Data composited for 2 harvests.

	Soil pH				
	4.8		6.2		
	0 µg P/g	48 µg P/g	0 µg P/g	48 µg P/g	LSD (5%)
P (%)	0.16	0.52	0.17	0.31	0.03
Al (ppm)	300	216	175	135	37
Mn (ppm)	724	782	252	458	39

The main features of these top-growth data are as follows: 1) the poor performance of both germplasms at pH 4.8 with no P addition, 2) the significant yield increase of the acid germplasm at pH 4.8 when P was added, 3) the significantly poorer yield of the acid germplasm at pH 6.2 with no P addition, and 4) the restoration of good yield for both germplasms with P addition at pH 6.2. From these data, it was tentatively concluded that at low pH and no P addition, where Mn and Al were

Table 2. Top-growth dry-weight yield (g/pot) for the acid-and limed-soil-selected alfalfa germplasms when grown in Cecil soil in greenhouse pots at two soil pH and two P levels. Data are total yields of 4 harvests.

	Soil pH			
	4.8		6.2	
Germplasms	0 µg P/g	48 µg P/g	0 µg P/g	48 µg P/g
Acid Soil Selections	1.60	6.02	6.87	25.86
Limed Soil Selections	1.25	5.66	9.71	20.97
LSD (5%)	NS	0.26	1.10	NS

toxic and P deficient (see table 1), very little productivity is found with even a germplasm selected for growth in acid soil. However, when P deficiency was overcome by P addition at pH 4.8, then the ability of the acid-soil-selected germplasm to tolerate the still toxic levels of Mn, and to a lesser extent Al (see table 1), was demonstrated. The characteristic of the acid-selected germplasm to respond in a dramatic way to P application was again found at pH 6.2, where it did significantly poorer than the limed-soil-selected germplasm at no P addition but better empirically with P addition. It is felt these data indicate that during selection in acid soil, those alfalfa plants which exclude toxic elements (mainly Mn, which more directly depresses top growth) were selected. But these plants may also exclude large cations such a P when these cations are at low levels or use P to neutralize toxic elements, especially Al, in their root zones. Therefore, it is only at high P levels (especially when Mn is toxic) that the acid-soil-selected germplasm expresses its full potential.

An experiment similar to the above greenhouse study was established in field plots of the Cecil soil. A split-plot design with soil pH x P levels factorialized as main plots and germplasms as subplots was used. The two P levels were 60 kg P/ha (that which would be normally recommended for this soil by the Univ. of Georgia Soil Testing Laboratory) and 140 kg P/ha. The four soil pH values were 4.7, 6.0, 6.6, and 7.0. The germplasms were the acid and limed soil selections as well as the cultivar 'Apollo', which was included as a check. This field experiment was harvested five times during 1981, and the tissue analyses for two pH treatments (4.7 and 7.0) are presented in table 3.

Although Al and Mn levels were not as high in the field as in the greenhouse (compare tables 1 and 3), the concentrations of both were changed appreciably by liming. No differences were found for changes in % P, probably reflecting the high amount of P applied at even the low rate. However, there was less Al

Table 3. Concentrations of P, Al, and Mn in alfalfa tissue (pooled by germplasms) when grown in the field at two soil pH and two P levels. Data composited for all harvests.

	Soil pH				
	4.7		7.0		
	60 kg P/ha	140 kg P/ha	60 kg P/ha	140 kg P/ha	LSD (5%)
P (%)	0.25	0.26	0.24	0.24	NS
Al (ppm)	245	179	102	108	24
Mn (ppm)	138	122	63	56	15

Table 4. Top-growth dry-weight yield for the acid- and limed-soil-selected germplasms and the cultivar 'Apollo' when grown in the field at two soil pH and at two P levels. Data are totals of 5 harvests during 1981.

	Soil pH			
	4.7		7.0	
Germplasms or Cultivar	60 kg P/ha	140 kg P/ha	60 kg P/ha	140 kg P/ha
	kg/ha			
Limed Soil Selections	940 (95)*	2519 (105)	7178 (99)	9022 (112)
Acid Soil Selections	807 (81)	3119 (130)	7452 (103)	8993 (112)
Apollo	992	2400	7244	8044

* Number in parentheses represents the % yield of that mean relative to the mean of the Apollo check cultivar in the same treatment.

and Mn as P was increased to 140 kg/ha at pH 4.7. Top-growth yields for the first year in these same two treatments are found in table 4.

There was a increase in yield for both germplasms and the Apollo cultivar as soil pH was increased, but all performed poorly at low soil pH. However, as seen in the greenhouse experiment (table 2), there was a trend of increased P application at low pH, causing an increase in yield of the acid-soil-selected germplasm relative to both Apollo and the limed-soil-selected germplasm. This trend was less dramatic at pH 7.0. These field data seem to support the hypothesis outlined above that the acid selections are at an advantage at high levels of P. This advantage of the acid germplasm at high P is especially pronounced if the soil possesses high levels of Mn and Al.

In another greenhouse experiment (Bouton et al. 1982), the rooting depth into acid subsoil of the two germplasms was tested in large boxes containing a repacked soil profile. A significantly higher amount of acid subsoil rooting was found with the acid-soil-selected germplasm when compared to the limed-soil-selected germplasm. However, field experiments are now being conducted to assess the rooting depth into acid subsoil and concurrent water use of these acid selections. Any increased water use should lead to better yield and would be the best test to prove the advantage of the acid-soil-selected germplasm.

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INSECT VECTORS OF VIRUSES IN LEGUMES AND CHARACTERIZATION OF THESE VIRUSES: MATERIAL AND TECHNICAL SUPPORT FOR APHID VECTOR SURVEY ACTIVITY OF REGIONAL PROJECT S-127

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Regional Research Project S-127, Forage Legume Viruses, initiated in 1977 to run through 1982, has recently been extended for an additional 5 years. Cooperative effort by project members has been concentrated over the past 5 years on Objective 1 of the project: to identify, characterize, and determine the distribution of viruses infecting forage legumes in the southeastern United States.

VIRUS DETECTION AND IDENTIFICATION

Enzyme-linked immunosorbent assay (ELISA) was adapted and refined for cooperative regional study of virus distribution (McLaughlin and Barnett, 1978; McLaughlin, 1979). Sensitized ELISA plates, mailed to cooperators from a coordinating location at Clemson University, were incubated with samples and returned by mail to Clemson for completion of the assay. The system facilitated detection of alfalfa mosaic (AMV), bean yellow mosaic (BYMV), clover yellow vein (CYVV), clover yellow mosaic (CYMV), white clover mosaic (WCMV), red clover vein mosaic (RCVMV), and peanut stunt (PSV) viruses in forage legumes. Viruses most frequently detected and identified were AMV, BYMV, CYVV, and PSV (Table 1). Other viruses such as tobacco ringspot virus, tomato ringspot virus, cucumber mosaic virus, peanut mottle virus, pea streak virus, WCMV, and RCVMV were less prevalent but were detected in local situations.

EPIDEMIOLOGICAL STUDIES OF APHID VECTORS

Cooperative research under Objective 1 of the regional project has improved knowledge of the identity and distribution of forage legume viruses. Provision was made in Objective 3 of the regional project for epidemiological studies to establish the importance of selected factors in the

Table 1.--Forage legume viruses identified through regional Project S-127

State	Virus[1]						
	AMV	BYMV	CYVV	PSV	RCVMV	WCMV	Others
AL	+	+	+	+		+	
AZ	+						PStV
FL		+		+			
GA		+					PMV, CMV
KY		+	+	+			
LA	+	+	+	+	+	+	
MD	+	+	+	+			
MS	+	+	+	+	+	+	
NC	+	+	+	+	+	+	TRSV
PA	+	+	+	+	+		
SC	+	+	+	+	+	+	
TN		+	+	+	+		
VA	+	+	+	+		+	PMV, TomRSV, TRSV
WI	+	+		+			

[1] Alfalfa mosaic virus (AMV), bean yellow mosaic virus (BYMV), clover yellow vein virus (CYVV), peanut stunt virus (PSV), red clover vein mosaic virus (RCVMV), white clover mosaic virus (WCMV), pea streak virus (PStV), peanut mottle virus (PMV), cucumber mosaic virus (CMV), tobacco ringspot virus (TRSV), tomato ringspot virus (TomRSV).

epidemiology of virus diseases in forage legumes. Because most forage legume viruses are vectored by aphids, study of their epidemiology must necessarily include research on aphid movement and virus transmission. However, only limited progress has been made in research within the regional project on aphid vectors as factors in the epidemiology of forage legume viruses. Participation of cooperators in vector studies has been limited because coordinated technical support has been unavailable and access to expertise for aphid identification has been limited.

A few cooperators have monitored vector movement by means of aphid trapping studies. Cyclical patterns in total aphid populations have been observed in Georgia (Demski and Kuhn 1977), Mississippi (Baer and Ellsbury 1982), and South Carolina (O. W. Barnett, unpublished data). In the 1980-81 Mississippi study (Fig. 1) flights of aphids were monitored in annual clover plots with vertical sticky board traps. Cyclical increases in numbers of aphids trapped occurred in

late April to May and in late fall. No attempt was made to correlate aphid movement with virus incidence.

A coordinated regional effort is needed to correlate virus transmission and incidence with vector movement and distribution. This can be done by combining aphid trapping studies with virus indexing of bait plants or test plants exposed to aphids.

APHID TRAPPING METHODS

Several trapping methods, with different attributes and advantages, have been developed for monitoring and surveying alate aphid populations. These trapping techniques were reviewed by Taylor and Palmer (1972). Major types of trapping devices include suction traps (Johnson 1950a), sticky traps (Broadbent 1946, 1948), and yellow water-pan traps (Moericke 1951). Several researchers have compared various trap configurations (Broadbent 1948, Eastop 1955, O'Loughlin 1963, Adlerz 1976) and found that efficiency of the traps and their specificity depended on the crop and aphid species being sampled.

Few aphid trapping studies have dealt specifically with aphid vectors and viruses of forage legumes. Johnson (1950b) studied infestation of field beans by Aphis fabae (Scop.). O'Loughlin (1963) monitored seasonal aphid occurrence associated with pastures and other crops in Australia. Gutierrez et al. (1974a) used yellow pan traps to study cowpea aphid, Aphis craccivora Koch, populations in relation to the epidemiology of subterranean clover stunt virus (SCSV) in southeastern Australia. Phenology and migration of A. craccivora were determined using a cooperative network of 32 trapping sites. Information from the trapping study and other laboratory studies (Gutierrez et al. 1971) was used to develop a predictive model for cowpea aphid populations in pastures (Gutierrez et al. 1974b). Transmission of SCSV occurred primarily during fall migratory movement of A. craccivora. The virus was confined mostly to subterranean clover as a natural host since the cowpea aphid preferred subterranean clover over other legumes present

In more recent studies, Irwin (1980), working with aphid-transmitted soybean mosaic virus (SMV), monitored aphid landing rates by means of clear plastic pan traps containing mosaic green ceramic tiles with reflective properties similar to those of soybean foliage. This particular trap configuration would be adaptable to a cooperative regional research effort on vectors of forage legume viruses because of its low cost and simplicity.

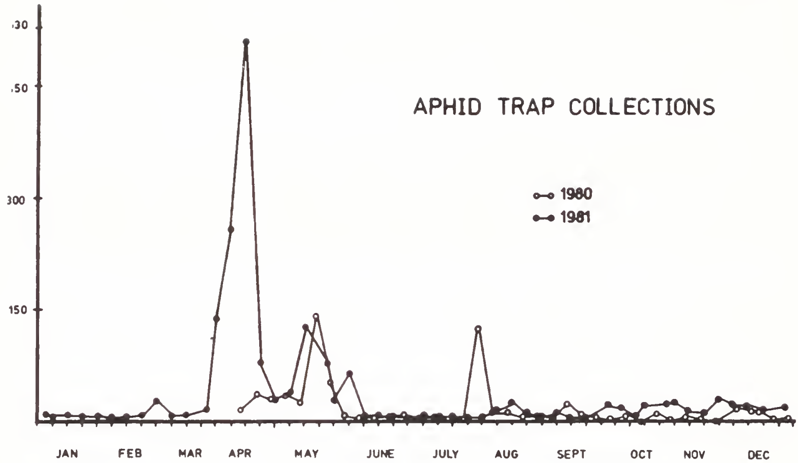

Fig. 1.--Number of aphids trapped weekly on a yellow vertical sticky board trap at Mississippi State, MS during 1980 and 1981 in association with annual and perennial clovers.

MATERIAL AND TECHNICAL SUPPORT FOR OBJECTIVE 3 OF S-127

Major research needs under Objective 3 during the coming 5 years of regional project S-127 include:

(1) survey and identification of aphid vectors of forage legume viruses
(2) determination of vector distribution and seasonal movement
(3) correlation of incidence of specific viruses with movement and distribution of aphid vectors.

Participants in S-127 have indicated that availability of expertise and support in the areas of preservation, trapping, curation and identification of aphid specimens would facilitate cooperative regional epidemiological studies of legume viruses. A second concern has been that such regional studies be performed using a standardizable trapping device so that data from each location will lend themselves to collective interpretation and lead eventually to a regional publication. In order to facilitate involvement of S-127 cooperators in regional forage legume virus vector research, the Forage-Livestock Research Unit of USDA-ARS and Mississippi State University propose to provide support to cooperators including

trap materials and supplies, specimen curation, specimen identification, and data management.

Traps

Material for mosaic green tile pan traps (Irwin 1980) to include one tile, one plastic container, and a support clamp for each trap will be provided in quantities needed for each cooperator's specific application. For each trap used, the cooperator would be expected to provide a 3/8" steel rod 5' to 6' long as a support standard, and trap fluid consisting of clear ethylene glycol diluted 1:1 with water.

Specimen Handling

Prepaid return mailers containing specimen vials and preprinted data labels for each trap unit will be sent each week for use during the succeeding week. Mailers should be returned to Mississippi State each week with aphid collections from the past week preserved in the vials. Technical support will consist of slide mount preparation and identification of specimens on a limited basis. The eventual goal of aphid trapping support and coordination will be to return data to each cooperator concerning numbers and identity of aphid species caught, along with slide mounts of identified specimens for reference use. Representative specimens would be retained and placed in the Mississippi Entomological Museum at Mississippi State University as a permanent reference collection of aphids from the Southeast.

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